# Control ENGINEERING

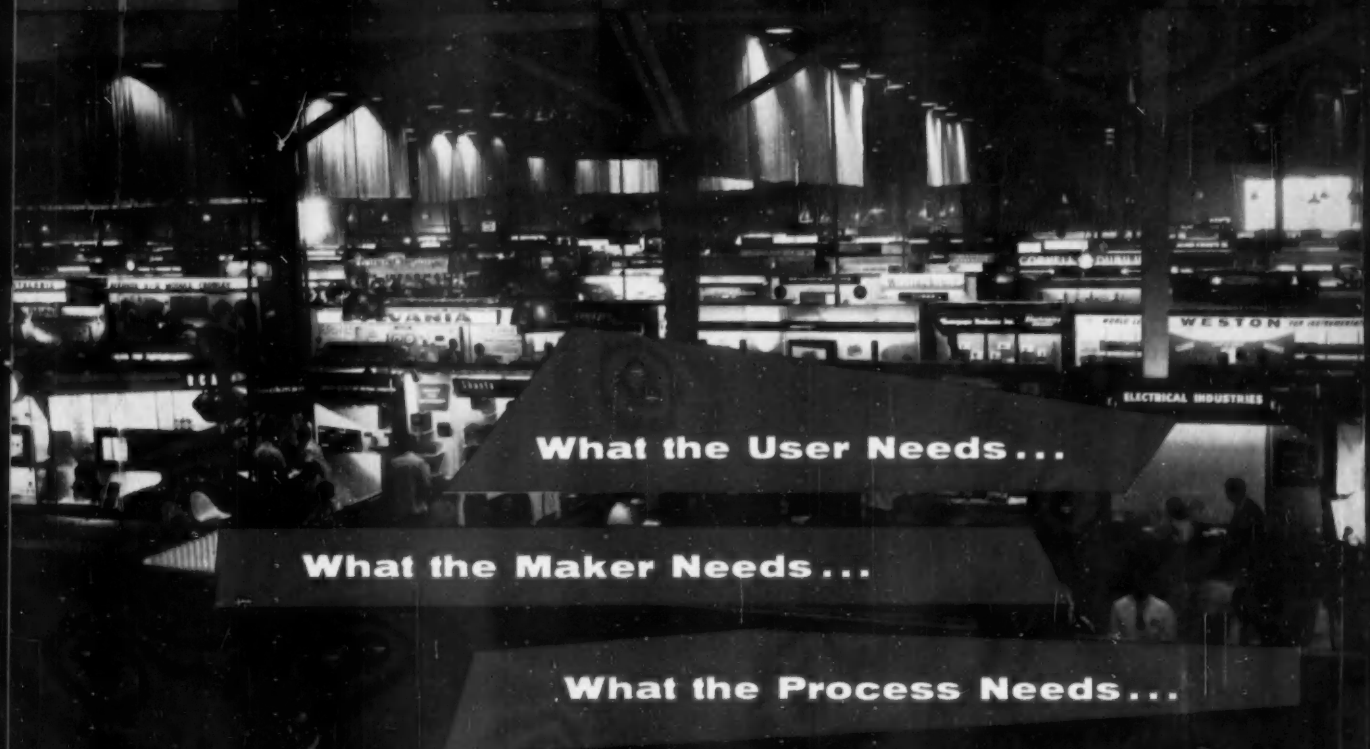
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 50 CENTS

NOVEMBER 1956

## The Needs of Industrial Control

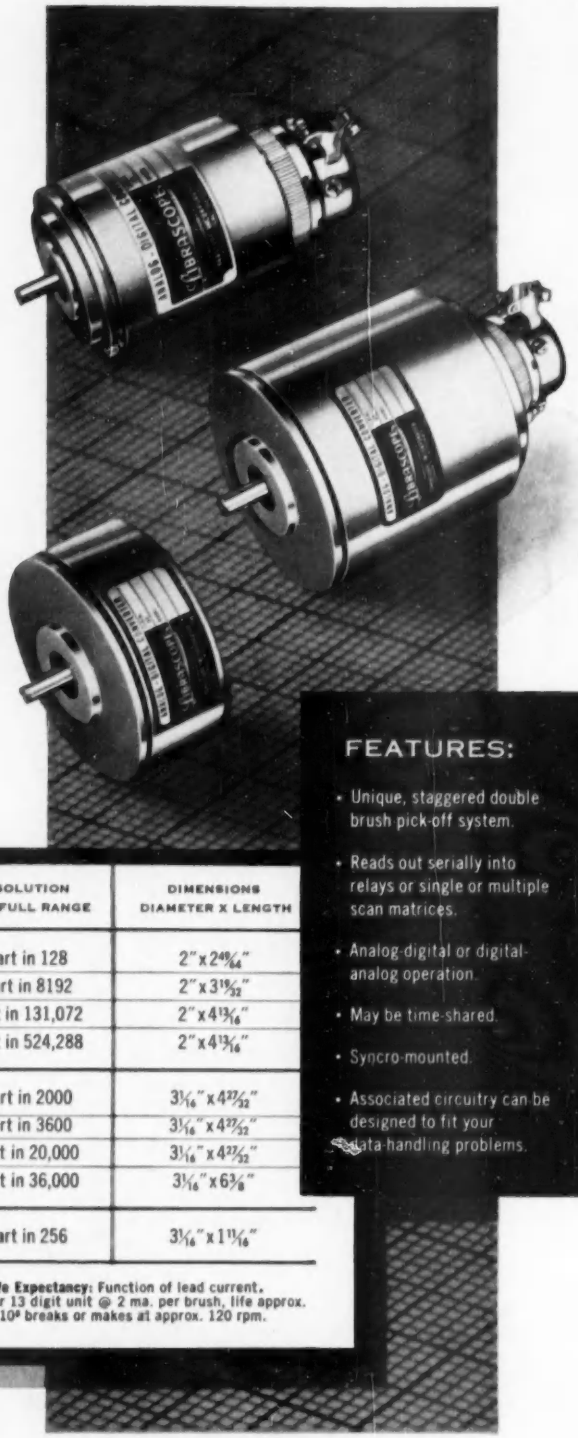


**Flexibility in Application**
**Versatility in design...**

# packaged analog-digital converters

**Shaft Position to Digital Converters** features reliability, long life, non-ambiguity and speed makes these converters ideal for computers or data handling systems where serial read-out is preferred. Librascope converters transmit information at almost any rate desired up to 1 mc and in some cases above, and may be multiple time-shared, holding extra circuitry to a minimum. All units quickly adjustable, syncro-mounted. Available in Binary, Gray code or Binary decimal code as shown in chart below. Special units may be designed to your order.

*Write for catalog information.*



| CODE | MODEL* | RESOLUTION PER INPUT SHAFT REV. | RESOLUTION OVER FULL RANGE | DIMENSIONS DIAMETER X LENGTH |
|---|---|---|---|---|
| BINARY | 7 digit | 128 | 1 part in 128 | 2" x 2 49/64" |
| | 13 digit | 128 | 1 part in 8192 | 2" x 3 19/32" |
| | 17 digit | 128 | 1 part in 131,072 | 2" x 4 13/16" |
| | 19 digit | 128 | 1 part in 524,288 | 2" x 4 13/16" |
| BINARY CODED DECIMAL | 0-2000 | 200 | 1 part in 2000 | 3 1/16" x 4 27/32" |
| | 0-3600 | 200 | 1 part in 3600 | 3 1/16" x 4 27/32" |
| | 0-20,000 | 200 | 1 part in 20,000 | 3 1/16" x 4 27/32" |
| | 0-36,000 | 200 | 1 part in 36,000 | 3 1/16" x 6 3/8" |
| GRAY | 8 | 256 | 1 part in 256 | 3 1/16" x 1 11/16" |

*SPECIAL UNITS AVAILABLE

**Precision gearing**
**Shaft Speed:** 120 rpm continuous
**Operating temp:** −55° C to +75° C
**Shock and Vibration:** up to 15 G, 5 to 500 cps.

**Life Expectancy:** Function of lead current. For 13 digit unit @ 2 ma. per brush, life approx. $5 \times 10^8$ breaks or makes at approx. 120 rpm.

## FEATURES:

- Unique, staggered double brush pick-off system.
- Reads out serially into relays or single or multiple scan matrices.
- Analog-digital or digital-analog operation.
- May be time-shared.
- Syncro-mounted.
- Associated circuitry can be designed to fit your data-handling problems.

*Engineers, physicists and mathematicians interested in challenging California careers, contact Mac McKeague, Personnel Director.*

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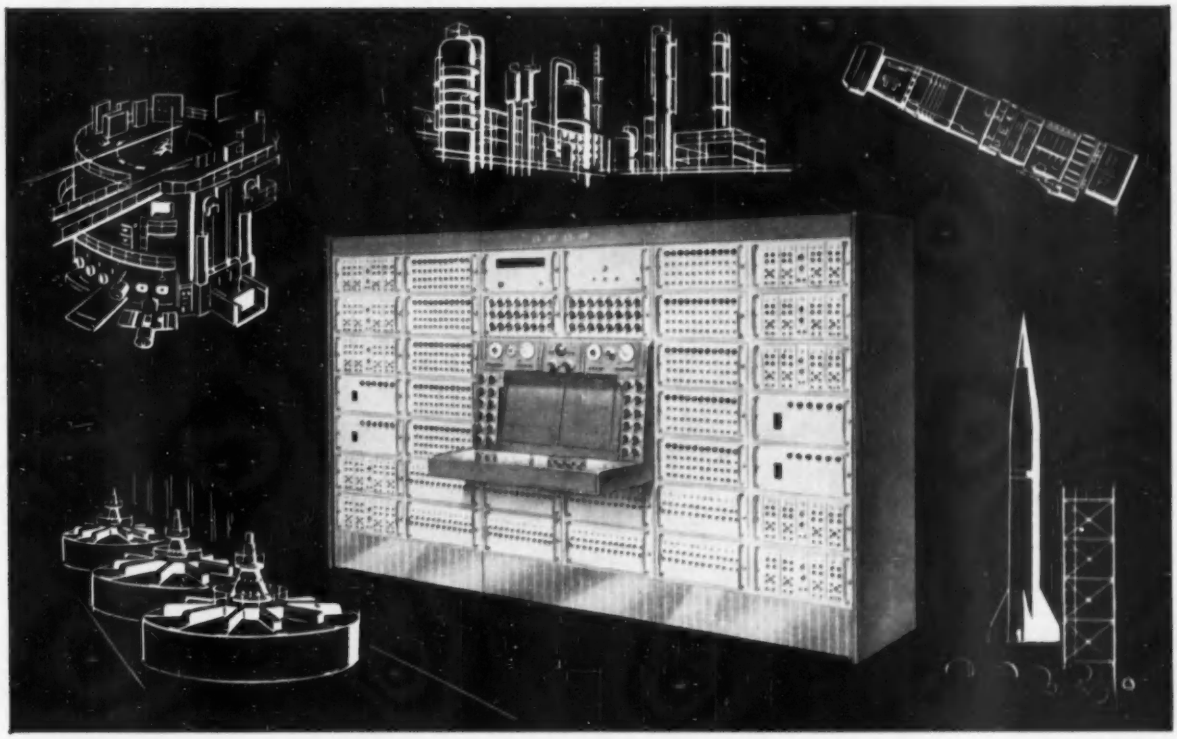

*among the problems we can solve for you...*

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**jet engine simulation**
**process control simulation**
**flight & guidance simulation**
**power dispatch simulation**

No matter which of these categories describes your engineering problems, there's a GEDA A-14 Electronic Simulator custom-designed to save *you* precious engineering man-hours.

These spectacular new electronic simulators present the first commercially available console operated analog computing systems individually designed to *specific* simulation problems. Available with as few as twelve, to as many as several hundred amplifiers – plus hundreds of nonlinear channels – these GEDA A-14 Electronic Simulators offer precision, flexibility, convenience and stability heretofore unknown in commercial installations.

With built-in features you cannot obtain even as options on other computers, the new GEDA A-14 Simulators offer the most accurate, widest band-width linear computing equipment *plus* the most precise high-speed, nonlinear equipment in the industry. And, with the new GEDA A-14, you have the widest selection of accessory equipment available.

Exclusive features such as Automatic Read-Out Printing, Automatic Dialing System, the unique split problem board for analyzing two separate problems simultaneously and many more, make the new GEDA A-14 the most advanced, most flexible analog computing systems ever offered to industry. And, you get these custom-built features at production economy.

We would welcome the opportunity to discuss the details of a GEDA A-14 installation – large or small – custom-designed to *your* exact requirements. Write: Goodyear Aircraft Corporation, Dpt. 931GW, Akron 15, Ohio.

• • •

**Now available is a new Goodyear Engineering Report, GER-7648, which describes the principles of operation of the GEDA A-14 Nuclear Reactor Simulator. Write now for your copy.**

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ANALOG COMPUTERS

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# FOR DRIFT-FREE DC INSTRUMENTATION

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INTEGRAL POWER SUPPLY

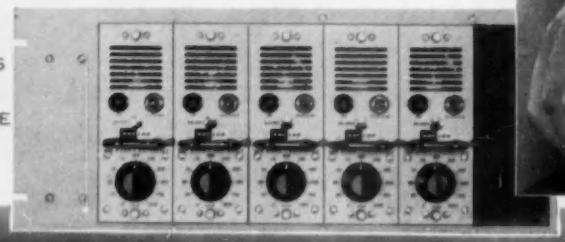
HIGH OUTPUT LEVEL

EXTREMELY LOW NOISE

BROAD BANDWIDTH

10 ACCURATE GAIN RANGES

HIGH INPUT IMPEDANCE



The **KAY LAB** Model 111 amplifier provides maximum stability and the lowest drift of any commercially available broadband d-c amplifier. It is the end result of years of research in the field of chopper stabilized broadband d-c amplifiers. Thousands of **KAY LAB** amplifiers are in daily use.

The Model 111 incorporates **KAY LAB's** proven chopper amplifier circuitry and provides ten extremely precise, feedback controlled gain ranges. Several feedback loops assure high accuracy, stability and uniform frequency response. The completely new and unique circuit provides rapid recovery from severe overloading and unsurpassed dynamic performance — unaffected by load or gain changes.

The Model 111 is available in a single-unit cabinet or in a six-unit rack-mountable module. The amplifiers are extremely compact: the six-unit module occupies only a 19-inch rack width.

APPLICATIONS: The Model 111 is ideal for permanent low level d-c instrumentation, telemetering, or as a strain gage amplifier, transducer amplifier, scope preamplifier, recorder driver amplifier, or general purpose laboratory amplifier.

## SPECIFICATIONS

| | |
|---|---|
| Gain | 0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000 |
| Gain Accuracy | ± 1% DC to 2 KC |
| Input Impedance | 100,000 Ω |
| Output Capability at DC | 0 to ± 35 V where $R_L$ > 1000 Ω<br>0 to ± 40 MA where $R_L$ is 10 to 400 Ω |
| Output Impedance | Less than 1 Ω in series with 25 μh |
| Equivalent Input Drift | ± 2 μv with regulated line |
| Equivalent Input Noise | 0 to 3 cps, less than 5 μv peak to peak<br>0 to 750 cps, less than 5 μv RMS<br>0 to 50 kc, less than 12 μv RMS |
| Chopper Intermodulation | Less than 0.1% |
| Linearity | Better than 0.1% to 2 KC |
| Frequency Response | ± 3% (0.3 db) DC to 10 KC, less than 3 db down at 40 KC |

| | |
|---|---|
| Power Requirements: | |
| Amplifier | 117 V — 60 cycles — 70 VA |
| Cabinet | 117 V — 60 cycles — 15 VA |
| 6 Unit Rack Adaptor | 117 V — 60 cycles — 45 VA |
| Dimensions: Amplifier Unit | 2⅞" wide, 7⅝" high, 14⅝" deep |
| Rack Adaptor for 6 Units | 19" wide, 8¾" high, 18¼" deep |
| Net Weight — Amplifier | 11 pounds |
| PRICE: Amplifier Unit | $550.00 |
| 19-inch Rack Adaptor for 6 amplifier (with fans and connectors) | 200.00 |
| Cabinet for single amplifier (with fan and connector) is available. | |

*...the Standard in chopper-stabilized instruments*

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Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

# Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

NOVEMBER 1956

**ISSUE THEME**



**FEATURE ARTICLES**



**IDEAS AT WORK**



**DEPARTMENTS**





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# SHOPTALK

A glance at our cover this election month, with its views of two great Control Conventions, shows that we, too, have a platform. It's "Meeting the Needs of Industrial Control". And not to be outdone by other campaigners, we've thrown in the gripping slogan, "Peace, Prosperity, and Potentiometers". Seriously though, in firming up this issue, we decided to clarify for our readers (and ourselves) the basic needs of our field. They came to three:

. . . more technical cross-fertilization—User Needs
. . . better field evaluation of product—Maker Needs
. . . closer liaison between users and makers—Process Needs

## MEETINGS MEETING THE NEED

Take the first need—more technical cross-fertilization of users of control. What could be a better sign that this need has been satisfied than the two recent conclaves held at opposite ends of the land? Start reading on page 25 to see how this need was met.

## USERS REVEALING THE NEED

Answering the second need—the need for better data on what is wanted in control product—*Industry's Pulse*, page 71, lets 719 users in the flow-process industries tell what they think about electronic vs. pneumatic equipment. And to add emphasis to this need, we asked our *Control Personality*, Vic Hanson, page 21, to write this month's editorial, page 79. Read it to see why the user often finds it necessary to meet its own equipment needs.

## TEAMS ATTACKING THE NEED

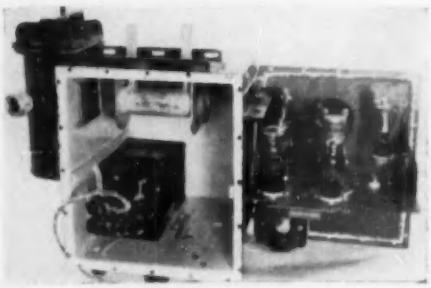
And then there is the third basic need—the need for user-maker cooperation to advance control. The du Pont-Burroughs story, page 83, shows what can happen when specialists on both sides of the fence team up on a project.

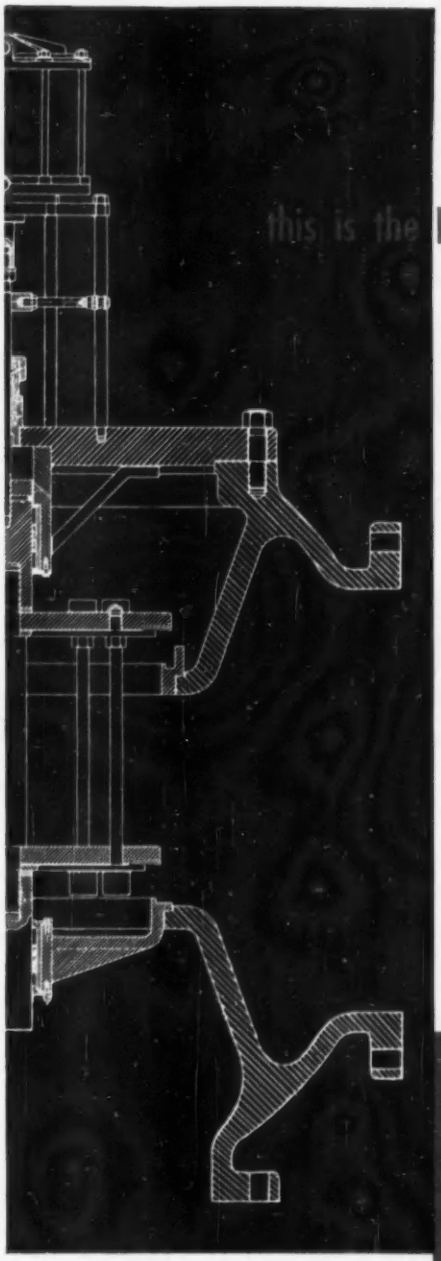
**Oh, Yes . . . Our Need**

There's a fourth basic need which we waited until now to mention, because it is peculiarly our own. It is a need on this staff for another prolific writing-type engineer from our field. Any ideas on how we can satisfy this need?

**He satisfied a need in '36**

On the right is Vic Hanson's famous electronic in-stream controller (page 21).





# this is the largest double-seated control valve ever made

When you are talking *big* control valves, talk to Kieley & Mueller. K&M is the largest manufacturer of the big ones, control valves above 16 inches. Standard globe-type valves are available in 20, 24, 30 and 36 inch sizes; even larger valves will be produced on special order.

This 36-inch double-seated angle valve closes snugly on giant Teflon seats. The inner valve positions responsively, gliding on special roller-slide bearings. It's massive, but is operates protected by a K&M patented torque resistor. Beyond the problem of size, this valve is mounted on its side, and it has been performing creditably for over four years.

BIG or small, if it's control valves, you'll like the pitch-in, helpful approach of your local K&M representative . . . plus capable engineering and manufacturing follow-thru at the K&M plant.

*Write for Bulletin CV-53.*

**ABOVE: Partial cross-section of K&M 36-inch valve showing general construction.**

**AT RIGHT: Actual size of a 36 inch valve can be visualized from this illustration of a workman inside the valve body performing finishing operations.**

K&M

KIELEY & MUELLER, INC.

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*78th Anniversary . . . Oldest U.S. Pressure and Level Control Valve Manufacturer*

# FEEDBACK

**Legal bits are redundant . . .**

TO THE EDITOR—

Kudos to CONTROL ENGINEERING for the brilliantly clear exposition (August 1956) of the U.S. Patent Office enigma—how to process the flood of applications against the geometrically increasing prior art recorded in the patents and technical publications of all lands.

After Patent Office Classification Chief Andrews has successfully harnessed his "ruly English" and Boolean algebra to conquer command coding, I suggest he turn his attention to the input to his computer, i.e., the patent applications we patent practitioners submit. Such a legal document, even though largely of technical content, cannot take the form of a "program". Among other difficulties, it would not be easy to convince most inventors, patent lawyers, examiners, judges, engineers, and scientists that they must become proficient in digital lore.

The heavily stylized form of application presently in use encourages redundancy both in the exposition of the invention and the claims. With the more precise requirements of a coding system in mind, no doubt the current format will have to be changed to one more easily translatable into such system.

*Stanley Wolder*
*New York, N. Y.*

**Managing Editor Slater tips his hat to his public; his report on the present and future of patent processing was well received. In the words of another respondent:**

The usual treatment of patents becomes bogged down in details of patent law. The unusual approach of discussing how the system operates makes very interesting reading. I have been active in patent law for many years, but many things in this article were new to me.

*Patent Attorney*
*Ramo-Wooldridge Corp.*

**It is our policy to publish in the Feedback section comments on the additions to articles and departments carried in the magazine. The additions may be improvements on techniques presented by authors in their articles. Here is an example. Turn to this section for more in future issues. Ed.**

TO THE EDITOR—

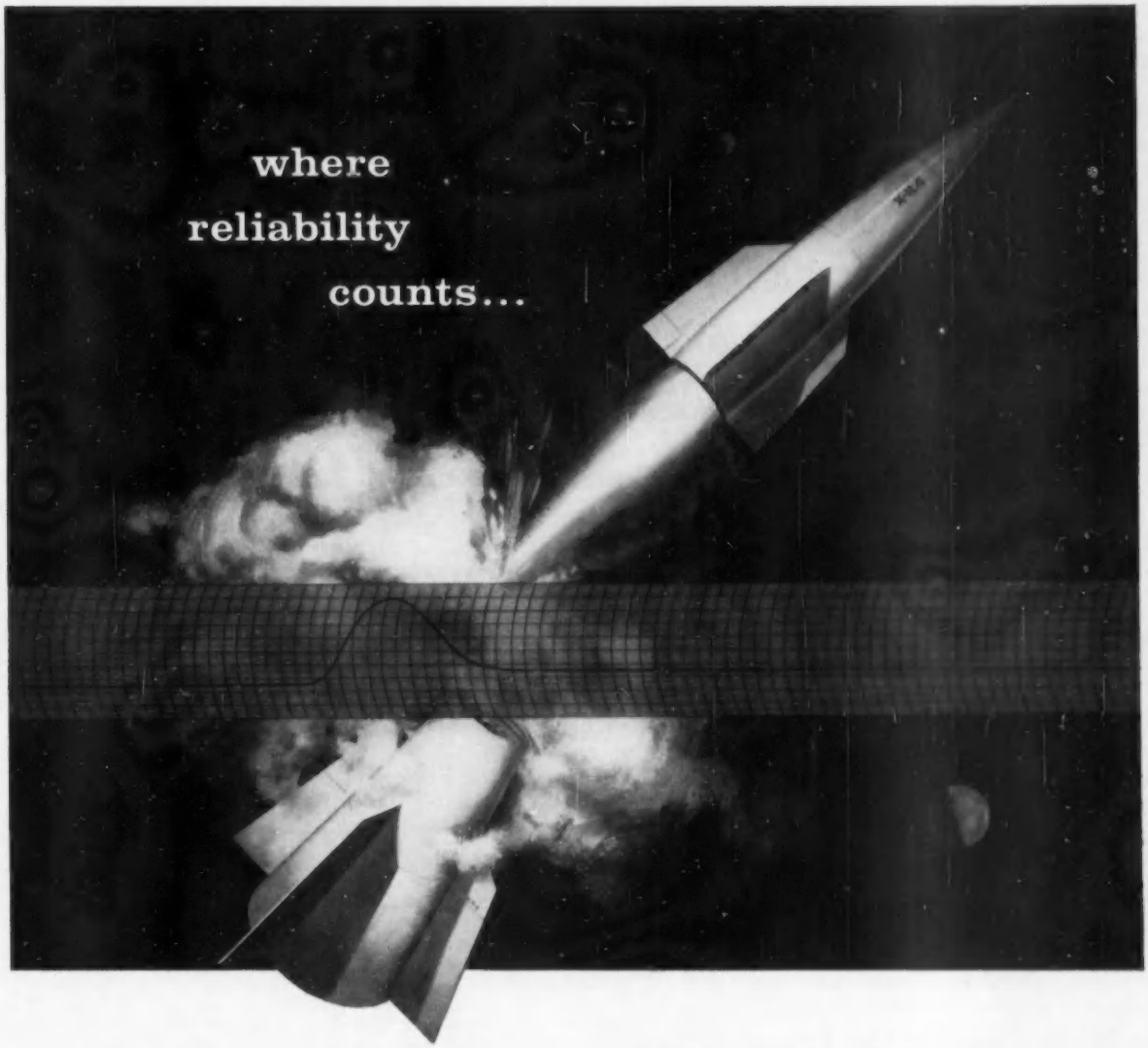
The analog computer circuit pub-

## PROBLEM FORUM . . .

**Appropriately in this election month, our problem deals with an urgent call from fast-growing Los Angeles County for a foolproof, mechanized ballot box. The county's Board of Supervisors, whose "contribution" is described in newsstory-fashion below, will consider any design provided that design meets some pretty challenging requirements. The supervisors would retain one patent right—to have the accepted equipment manufactured without payment of royalty—but all other rights would remain with the contractor. And that suggests something well to remember: this time the modest CtE cash awards to be paid for the best solutions will take a back seat to a much more important prize—a handsome contract for your firm. All answers, of course, will be forwarded to Southern California.**

There's a tall order in data processing waiting to be filled today in one of the most dense electronics areas in the country. The area is, of course, Los Angeles, and the challenge there comes from the County Board of Supervisors, which is looking for a way to simplify, speed up, and economize on its ballot-tallying system. It is an interesting coincidence that what probably is the first direct plea of this nature to makers of automatic control devices should be made by overseers of the nation's most complex voting system, and should originate in

*(Continued on p. 16)*



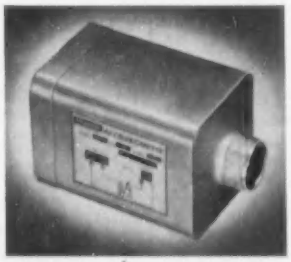

## ...Giannini AC output, inductive pickoff accelerometers are specified

Giannini AC output, inductive pickoff accelerometers provide the precise accuracy and consistent reliability demanded by today's high speed, high altitude aircraft and missiles.

Supplementing the wide range of Giannini potentiometer output accelerometers, the Series 24611 are ideal for accelerometer applications requiring superlative performance in the most critical airborne guidance and control systems. Through virtually frictionless inertial mass suspension, the magnetically damped Series 24611 Accelerometers offer extreme sensitivity and low threshold; and, as in all Giannini products, RELIABILITY is their distinguishing feature.

WHERE RELIABILITY COUNTS, the Series 24611 is the criterion for accurate, consistently reliable AC measurement of linear acceleration.

*For further information, write for Bulletin 24611.*



**Specifications:**

RANGES... ±0.25g to ±10.0g

THRESHOLD SENSITIVITY ...as low as $10^{-4}$g

AC OUTPUT...to 20v/g

REPEATABILITY ...better than 0.1%

DAMPING ...magnetic, no coulomb friction so that response follows faithfully that of a second order resonant system.

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## FEEDBACK

lished in my article, "An Analog for Process Lags", CONTROL ENGINEERING, October 1956, has certain limitations that can be overcome by the addition of another operational amplifier. The circuit in the article permits "continuous variation of delay time"; that is, selection of any of an infinite number of delay times between zero and the suggested 11-sec limit, "but not without distortion during variation". This means that the circuit cannot simulate a process lag that varies during operation, a conclusion that might be inferred from the summary paragraph at the head of the article. That circuit also has the limitation of increasing output noise as the delay time is made shorter, becoming serious for delay times of less than about one second.

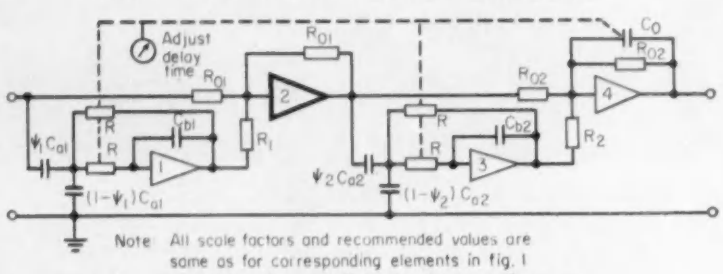
I enclose the "modified circuit" referred to in the article, which requires an additional operational amplifier (Number 2), and which does permit simultaneous variation of delay time and input signal without distortion of the signal. This circuit also avoids the noise limitation—its noise level will be less than 10 mv rms even at zero delay time ($R = 0$). The reduced noise characteristic eliminates the need for $C_o$, thus allowing dynamic variation of delay time by simply using ganged servo-driven potentiometers for the $R$'s.

Since some of the early work was done jointly with Gilbert S. Stubbs, I would like to call particular attention to the first reference given in the [following] bibliography [for last month's article[1]]:


1. *Transport Delay Simulation Circuits* (WAPD-T-38), G. S. Stubbs and C. H. Single, Westinghouse Atomic Power Div., Technical Report 38, May 1952.
2. Supplement to Reference 1.
3. *A Sub-Audio Time Delay Circuit*, C. D. Morrill, "Trans. IRE", PGEC, Vol. 3, June 1954, pp. 45-49.
4. *Time Delay Networks For an Analog Computer*, W. J. Cunningham, "Trans. IRE", PGEC, Vol. EC-3, No. 4, December 1954.
5. *Time Delay Circuits For Analog Computers*, C. H. Single, Beckman Instruments, Inc., bulletin.


*C. H. Single, Richmond, Calif.*

A DYNAMICALLY-VARIABLE ANALOG FOR PROCESS LAGS




Note: All scale factors and recommended values are same as for corresponding elements in fig. 1 of article referenced. This circuit has no $R_3$

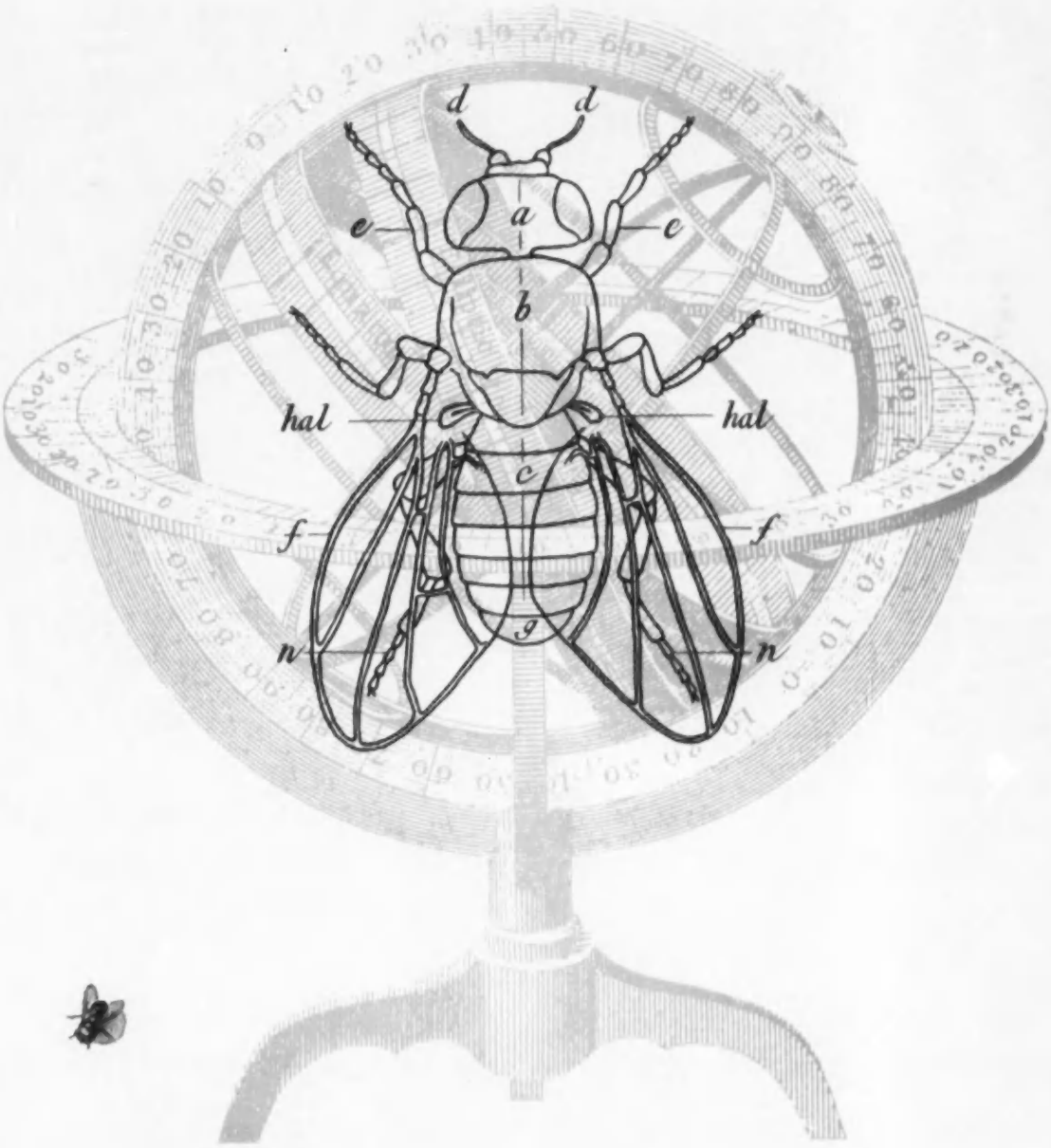
**For the record . . .**

TO THE EDITOR—

We note in your September 1956 issue, page 244, that you announced the development of a "Shaft Digitizer" by Jones & Wettlaufer Engineering Corp. Though the term "Digitzer" lends itself naturally to the description of analog-to-digital conversion equipment and was obviously not used with deceptive intent, we should like to call your attention to the fact that it is the subject of trademark No. 588,177 on the Principal Register of the United States Patent Office. This trademark was issued 13 April 1954 to Coleman Engineering Company, Inc., and applies to electromechanical contact-setting devices for indicating position of a rotatable shaft.

We believe that any use of the mark "Digitzer" in connection with similar goods not manufactured or licensed by Coleman Engineering Company, Inc. will result in confusion in trade with regard to the source or origin of the goods, and so constitute an infringement of the registered trademark. As such confusion can react to the disfavor of all concerned, we feel sure that you will understand our request that the use of the term "Digitizer" as a generic designation for analog-to-digital converters be avoided.

Since we have called to your attention our use and registration of the mark "Digitizer", we hope that you will agree with our own point of view with regard to its application. We feel that it is not only to our own interests, but also to those of your readers, con-




## Two-Hundred-Million-Year-Old Inertial Navigator

EONS AGO the fly had two sets of wings. His second set of wings shrivelled into the vibrating gyros entomologists call halteres. The fly now flies with his own inertial guidance system, efficient enough for his needs and marvelously compact. Our interest in the anatomy of the fly is the interest of an inertial-guidance-systems Engineer. We construct inertial guidance systems. Those bearing the Litton Industries name have a simplicity of design and compactness unsurpassed in this complex field. They are designed to function at Mach Numbers that are classified.

**LITTON INDUSTRIES** BEVERLY HILLS, CALIFORNIA

*Plants and Laboratories in California, Maryland, Indiana and New York*

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MICROWAVE POWER TUBES · AUTOMATIC DATA PROCESSING SYSTEMS · SERVOMECHANISMS · SPACE SIMULATION RESEARCH

## FEEDBACK

tributors, and advertisers that a mark which has become established in trade should not be applied to similar or competitive goods.

*W. E. Martin*
*Coleman Engineering Co., Inc.*
*Los Angeles, Calif.*

**Certainly it is in the best interests of readers, contributors, and advertisers to clarify any confusion in the use of registered marks. As publication, in a national magazine, of engineering innovations and of registered marks is recognized as evidence by the United States Patent Office, we gladly publish Mr. Martin's clarifying letter. We point out, though, that the term "Shaft Digitizer" does appear on the face of the Jones and Wettlaufer product. Ed.**

**We furnish CSE too . . .**

To the Editor—

In looking through the September 1956 issue of Control Engineering we discovered the list of sources for control systems engineering contained on pages 92 and 93. We are interested in knowing what methods were used in determining these sources.

We noticed that under motor control manufacturers the only source listed was the Reliance Electric & Engineering Co. of Cleveland, Ohio. We, as control manufacturers, have been active in this field for a good many years and we know that most of our major competitors have also.

*Paul R. Goudy*
*Square D Co.*
*Milwaukee, Wis.*

**The sources listed were meant to be representative, not complete. In fact the Industry's Pulse referred to by Mr. Goudy states, "Despite the fact that many important practitioners were undoubtedly missed in this arbitrary mailing of questionnaires, the 27 detailed answers received offer an interesting view of the 'state of the art' as it can be bought by any manufacturing firm not itself equipped to follow the steps of control systems engineering." If complete in each of the five groups selected, the list would have run for many pages—pages not budgeted for that issue. Ed.**

**SIC mongrel still bites . . .**

**Recently our elder sister magazine, Business Week, published in an article on business activity the statement that the instrument industry showed "re-**

Emery NEWS
WEIGHING SYSTEM

VOLUME 1 NUMBER 2

# INSTRUMENT MEN HAIL CONCEPT OF WEIGHING SYSTEM "PACKAGE" SHOWN IN NEW TANK & BIN WEIGHING BOOK


Figure 1.

Visitors to the Emery booth at the recent ISA Show in New York City agreed, almost to a man, that the tank and bin weighing system purchasing has come nearer than they thought possible to a 'package deal'.

By using fifteen different tank weighing arrangements, we have been able to approximate practically every possible application. The purchasers need only select the arrangements which characterizes his application; select the proper brand of instrumentation; fill out a simple questionaire; and receive a quotation covering the best weighing system for his particular needs.

Figure 1 shows a series of these arrangements taken from our new Bulletin 561 . . . one of the most complete tank and bin weighing bulletins available.

Instrumentation from eight leading manufacturers is pictured in the bulletin and purchasers are invited to select the instrumentation they want with their weighing system.

If you have not yet received your copy of our new tank and bin weighing bulletin, write for it today.

# NEWLY DESIGNED EMERY CELL RUGGED & TROUBLE FREE

The new Emery Hydraulic Load Cell . . . the "heart" of the Emery tank and bin weighing system . . . is one of the most rugged pieces of weighing equipment available for industrial use.

The cell incorporates the new "rolling ball" principle which is specifically designed to accommodate normal expansion of the tank, off-center loading, bending of the tank brackets, and yielding of the supporting structure. These conditions occur, to some extent, in practically every installation.

Inherently rugged, they are built on the piston-cylinder principle in which the cell, itself, acts as a transducer by converting load to hydraulic pressure and measuring it with amazing accuracy. Instrumentation is available for practically every automatic indicating, recording or controlling function.

Before you buy a tank weighing system, investigate the rugged, durable, and accurate Emery Cell.

## SPECIAL WEIGHING SYSTEMS FOR SPECIALIZED APPLICATIONS

Although we make much of our newly-designed weighing system "package", our engineers with years of experience in weighing system design and manufacture will gladly review your specialized applications and make a recommendation.

By either modifying an existing design, or designing new equipment, we can satisfy the needs of any weighing application with rugged and accurate equipment.

## BALL PIVOT ASSEMBLY INCORPORATES "ROLLING BALL" PRINCIPLE

The principle of the "rolling steel ball" which has been so successfully designed into the new Emery Hydraulic Cell has recently been incorporated into the Emery Ball Pivot Assembly.

The Ball Pivot is used as a second or third point loading device in tank weighing applications where structural conditions of the application and the contents of the tank to be weighed permit the use of several pivots and an Emery Cell.

Thus, the same advantages present in the Emery Cell as a result of the "rolling ball" principle have been extended to the Ball Pivot Assembly.

Thus, the combination of the Ball Pivot Assembly and the Emery Cell, with its "rolling ball" head, are engineered to meet the requirements of actual working conditions.

## INSTRUMENTATION AN IMPORTANT FACTOR IN TANK & BIN WEIGHING APPLICATIONS

Recognizing the varying degrees of preference and importance in the teaming up of certain instrumentation with the proved performance of the Emery Hydraulic Load Cell, we have left the choice of instrumentation in tank and bin weighing systems up to the user.

In our new Bulletin 561, we list and picture sample types of instruments made by such manufacturers as ATC, Honeywell, Leeds and Northrup, Bristol, Taylor, Foxboro and Moore. Further, we indicate which manufacturer does and does not make equipment for the various functions of indicating, recording and controlling.

Either you can specify, or we can recommend what we think is suitable instrumentation for your needs. In that way, every customer can get exactly the instrumentation he wants.

THE A. H. EMERY COMPANY
Pine Street • New Canaan, Conn.

## FEEDBACK

cession symptoms". We rushed to our July issue, fondled its cover, and reread that issue's Industry's Pulse and the feature news item on pages 16 and 17. Our story did not jibe with BW's at all.

Within days we received from F. G. Goggin, Detroit Controls Corp., a postal lash for BW's apparent abberation. What to do but pass it on to Ken Kramer, Managing Editor of BW? Here, in part, is his answer to Mr. Goggin. It repeats the message of our July editorial—"Needed: a New Industry Breakdown".

"The 'instrument' classification itself is getting more and more fouled up—'impure', as the statisticians like to put it. In addition to the people who make instruments for such obviously expanding lines as atomic energy, chemical manufacturing, etc., it includes—for example—optical equipment and lenses, surgical instruments, even photographic equipment and it fails to include many instruments made by diversified companies. FTC experts say these are the reasons the class can go in one direction while individual instrument makers can be going the opposite.

"Obviously, if we had been aware of this mongrel breed of statistic, we would have done one of two things: (1) drop it out entirely, or (2) use it with a full definition of what is included in the category."

We're still campaigning for an improved SIC. Keep sending your suggestions in. Ed.

### When transistors overload . . .

In the article, "Applying Power Transistors to Control," page 78 of the October issue, author Aronson points out that transistors can be overheated for short times that depend on the time constants of the transistor and its heat sink. Accurate calculation of the signal frequency at which the transistor will overload is difficult. Because rigorous methods seem unreasonable, we asked Aronson to develop some rules-of-thumb which would give the applier of power transistors some "ballpark" figure for frequency limits. Here's his answer.

To the Editor—

If a transistor were mounted on an ideal infinite heat sink, the heat dissipated in the transistor would be drawn off by the heat sink without the heat sink itself increasing in temperature. Since the transistor would be cooled by the heat sink, it could be operated at a higher power. Practically speaking, a heat sink does in-

In
POWER
STATIONS or
CARGO
SHIPS...

# EDISON OMNIGUARD IMPROVES OPERATING EFFICIENCY

Whether you're seeking more production from electric power stations and plant equipment or greater safe speed from seagoing vessels, you will find Omniguard can help you get more efficiency from your present equipment.

Many operators are already using Omniguard, the unique temperature indicating and alarm system designed by Thomas A. Edison, Inc., as the best means of eliminating waste due to downtime, repairs and lost production.

Omniguard improves plant efficiency and lets you operate at peak capacity because it unfailingly reports when dangerous temperature conditions occur at one or more points. And does it at surprisingly low cost.

A modular system of monitoring one to an unlimited number of points simultaneously, Omniguard watches continuously. When a bearing starts heating up or a process becomes critically hot, it automatically gives a warning and/or shuts down the equipment before it is damaged.

The low cost unit is easy to install. It is non-electronic and simplifies installation and maintenance through the use of copper wiring between all components.

See for yourself. A personal demonstration can be arranged at your own plant. Take it apart. Analyze it. Find out how simply Omniguard improves operating efficiency. Just write!

*Thomas A. Edison*

A GREAT NAME CONTINUES GREAT NEW ACHIEVEMENTS

**Thomas A. Edison**

INCORPORATED

INSTRUMENT DIVISION • 38 LAKESIDE AVENUE • WEST ORANGE, NEW JERSEY

## FEEDBACK

crease in temperature as power is dissipated in the transistor, but during the short time interval after the application of power, temperature does not significantly increase. For this period of time the heat sink can be considered infinite.

The period of time can be estimated from the heat-sink initial thermal rate, given in deg C/sec, for a particular thermal current in watts. If a change $\Delta T_s$/deg C is considered the limit of temperature increase for an infinite heat sink, and if the applied power is known, then the time it takes for the heat sink to experience the temperature change can be found from the equation for the initial thermal rate,

$$\frac{dT_s}{dt} \simeq \frac{\Delta T_s}{\Delta t} = \frac{I_t}{C_p \times 4.19} \quad . \quad . \quad . \quad (1)$$

where: $T_s$ is the heat sink temperature, deg C
$t$ is the time, sec
$I_t$ is the thermal current, watts (see article for conversion)
$C_p$, the heat capacity of the heat sink material, is equal to the product of specific heat, density (grams/cc), and volume (cc) of the heat sink.

Equation 1 shows that the approximation of an infinite heat sink (an allowable $\Delta T_s$ of about 2 deg C) depends, for a given heat-sink design, on the thermal current and the time during which the peak current is applied. Thus, a large power can be applied for a short time, or a small power for a longer time.

When thermal current is applied to the heat-sink-transistor combination, the rise of temperature is actually exponential. However, Equation 1 shows that the initial rate of temperature rise is approximately linear within the time interval (sec) less than $\frac{D^2}{5}$ . . . . . (2),

where $D$ is the smallest dimension (cms) of the heat sink and applies to aluminum and copper heat sinks.

Equation 2 serves to check whether the heat sink designed for a steady dissipation can handle required peak power for the time $\Delta t$. If Equation 2 yields a value greater than the time $\Delta t$ used in Equation 1, the heat sink acts infinitely with peak thermal current and other conditions used in Equation 1 for pulse durations up to $\Delta t$. But if the value is smaller, the heat sink's volume must be increased and Equation 2 recalculated until its value is greater than $\Delta t$.

*H. L. Aronson*
*Cambridge, Mass.*

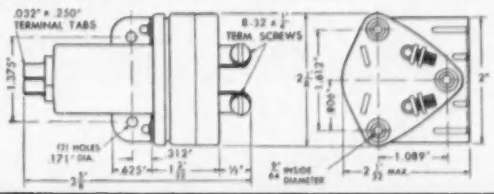
# for *Better Control* of MOTOR and HEATER units


## NEW! *The* GUARDIAN POWERLOID*

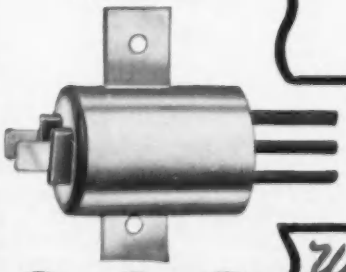
★ Designed by Guardian—this new POWERLOID offers definite advantages which are far ahead of anything being offered for the electromagnetic control of motors (tested for 230 v., A.C. loads, up to 3 H.P.) and heater units (up to 8400 watts). Rugged, totally enclosed . . . low priced!

**CONTACTS:** S.P.S.T. dual make, or S.P.S.T. dual break; or with S.P.D.T. dual make and dual break. Also, with S.P.S.T. dual make, or S.P.S.T. dual break utilizing an auxiliary switch on the outside of switch housing. **COILS:** standard voltages up to 230 v., A.C., 60 cycles and up to 110 v., D.C. **CONTACT TERMINALS:** 8-32″ x ¼″ Screw Type; Spade Coil terminals, .032″ x .250″ tabs designed for A.M.P. female receptacles. Assigned **CONTACT RATINGS:** 3 H.P. U/L motor load at 230 v., 60 cycles—6000 watt resistive load—500 watt Tungsten Lamp load.

*An electromagnetic switch actuated by a solenoid plunger.




## *The* GUARDIAN RELOID*



The Guardian RELOID, an electromagnetic switch actuated by a plunger, is rapidly becoming the accepted standard by leading manufacturers of electrical home appliances, vending machines and similarly powered units. Totally enclosed in a sturdy metal case, Guardian RELOIDS are resistant to moisture, dusts and impacts—withstand rough handling on assembly lines. Priced Low!

**SPECIFIED *for*:**
WASHING MACHINES
DRYERS (High Speed)
AIR CONDITIONING EQUIPMENT
REFRIGERATION EQUIPMENT
BATTERY CHARGERS
BUILT-IN AND ELECTRONIC OVENS
MAGNETO STARTERS
HEAT CONTROLS
HAIR DRYERS
*plus Many Other Applications*

*Write* Arrange for delivery of Production Samples and quotations on Guardian POWERLOIDS and RELOIDS.

GUARDIAN'S 25th YEAR

## GUARDIAN ELECTRIC

1623-M W. WALNUT STREET CHICAGO 12, ILLINOIS

*"Everything Under Control"*

a section appropriately dubbed "colussus of control" (CtE, March '56, p. 55).

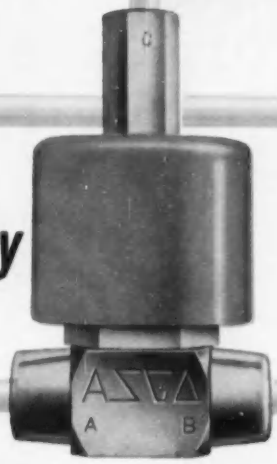
But until somebody comes up with a solution to its problem, this coincidence will continue to mean very little to a county whose registrar of voters has to keep tabs on about 200 elections annually, each one of them supervised by 50,000 clerks in 10,000 precincts, and all of them wrestling with more and more cross-marked ballots as the population of the county takes a jump of 165,000 every year.

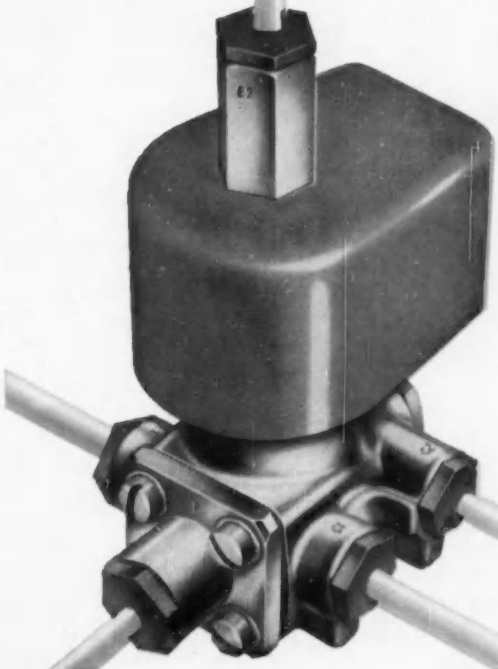
If the number of precincts can be cut in half, says the Board of Supervisors, so can the cost of each election, and the way to accomplish the first is to increase the capacity of each precinct. Here is where electronic data processors would play their biggest role. They would not chop into the per-day cost of operating each precinct (now $93, including salaries and rent), but would, believes the board, allow a precinct to handle 600 voters, or twice as many as it handles today. When you multiply $93 by 10,000 (the number of precincts), you get a product close to $1 million for each major election. Cut that in half and you have a handsome savings indeed.

But if there is going to be savings in manpower, says the board, it can't be done at the expense of the remaining 25,000 precinct workers, some of whom can be found counting ballots up to 4 o'clock on the morning after an election. Thus there must be some machinery for simplifying the process right in the precinct house. And that's another part of the problem: each of the 5,000 precincts still existing would need at least four automatic vote-talliers, which means 20,000 such machines for the whole county. This, declares the board, just won't do.

What alternative is there, then? To tally the ballots at receiving stations, of course, immediately after the voter's preference or choices have been identified at the precincts. This idea implies the use of mark-sensing techniques such as magnetic-ink recordings or photoelectric processing of ballots. This system would fulfill two requirements: first, it would keep the amount of equipment needed to a minimum, and second, it would permit the receiving stations to relay "snap tallies" for candidates or issues to the public and the press, which an automatic system would have to do anyway to be acceptable. Components would have to be developed—at the precinct level, naturally—that can convert information (principally a cross

# There's 1 source for 2 way 3 way or 4 way MIDGET SOLENOID VALVES





SHOWN ¾ ACTUAL SIZE

Progressive designers, the men who lead the trend toward miniaturization, depend on ASCO as the one source for a full line of midget solenoid valves. The unexcelled quality and dependability that ASCO pioneered in the solenoid valve field is found, too, in today's midget solenoid valves. Only the size has been reduced.

For flow applications using air, gas, water, light oil, refrigerants and many other liquids, ASCO Midget Valves assure complete safety and truly exceptional performance.

ASCO Midget Solenoid Valves are available with standard, watertight or explosion-proof enclosures. Pipe sizes ⅛" and ¼"; pressure range 0-1000 psi.

There's *one* source that solves virtually any solenoid valve problem – ASCO. Write today for complete data on ASCO Midget Solenoid Valves – or outline any of your requirements. We'll be pleased to assist you.

**ASCO**

Automatic Transfer Switches®
Electromagnetic Controls
Solenoid Valves

Automatic Switch Co.

395-B Lakeside Avenue • Orange, New Jersey

## FEEDBACK

made with a rubber stamp) into input media acceptable to different tallying devices such as punched tape or cards, or magnetic tape.

The board is confident that companies bidding on its contract will be able to get around the restrictions in design posed by California's cross-filing system, by its healthy encouragement of write-in votes, by the secrecy necessary for the type of information handled, and finally, by two voting regulations that could play havoc with any "yes, no" binary method of tabulation. One of them concerns the number of choices allowed for any one office, the other a requirement for rotating candidates on ballots.

Take the first one: the systems or devices proposed should be so designed that they will not count more crosses or choices than allowed. For example, should a voter select two candidates for an office where he is limited to one vote only, both of his choices should be discounted. Easy? Be it known that the highest number of choices allowed for any single office in California is seven. Take it from there.

Rotating in sequence is another obstacle that must be hurdled. By California law, each candidate for a given office (except the incumbent, who is always first), must share every position on a ballot with every other aspirant. This means that all of Los Angeles' 12 congressional districts and 31 assembly districts do not see the same ballot, although they all participate in the same election. In fact, says the board, one ballot appeared no less than 575 different ways! This may be fair to the candidates, since they all get an equal chance, but is it fair to the electronic system that does the tallying? The board won't commit itself on this point; it just asks that a suitable method for identifying a particular candidate in continuous totals be built into the proposed system.

### FACTS ON THE BIDDING

*Here are some dates the board would like you to keep in mind: Closing date for prototype equipment bids, Dec. 4, 1956; desired date for delivery, December 1957; evaluation period, the first six months of 1958; completion of procurement, December 1958; delivery of production quantities of equipment, December 1959; general use of equipment, the beginning of 1960. Instructions for preparing the proposal are more or less standard. When drawn up, it should go to the Los Angeles County Board of Supervisors, 501 Hall of Records, Los Angeles 12, Calif.*

# HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

## ENGINEERING NEWS #1

### SOLVE SPACE AND WIRING PROBLEMS with Switch/Light Combinations

You probably use these Hetherington Switch/Light combinations every time you travel via leading air lines. Here they are used as hostess call lights. As you may have suspected, however, this is just the beginning of their usefulness—both in aircraft as well as in commercial instrumentation and control uses. Their unique combination of single- or double-pole switching action together with an illuminating push button offers definite advantages in terms of greatly reduced panel space and the elimination of switch-to-light wiring. Usually the entire assembly takes no more space than a conventional switch alone.

Of particular importance for many applications, Hetherington Switch/Light combinations make it easier for operators to keep closer tabs on crowded panels without confusing control functions. By connecting the light to an externally controlled circuit the illuminated button virtually cries, *"Push Me,"* to attract the operator's attention at the right time. In other models, lamp circuits are controlled by the main switch contacts or by a second set of auxiliary contacts.

Typical contact ratings are 15 amps at 30 volts ac-dc. Illuminated buttons can be made in virtually any color, shape or size.

### HERE'S EXTRA SAFETY FOR WARNING LIGHT APPLICATIONS

JUST "PRESS TO TEST"

Ever wonder whether a warning light for a critical circuit was merely OFF or whether the bulb was burned-out?

If so, you'll appreciate the "Press-to-Test" feature of this tiny Hetherington Type L3200 light.

The lamp and its circuit can be "checked-out" simply by pressing on the spring-mounted plastic lens cap. This makes contact through a separate third terminal circuit. When cap is released, the lamp functions through the regular circuit.

The long plastic lens of the L3200 gives wide, 180-degree visibility with either standard or edge-lit panels. Uses AN3140 lamps. For more details, write for Bulletin L-2b.

### BETTER SWITCHES FOR BETTER APPLIANCES

A good electrical product deserves a good switch—and for types in the 5 to 50 ampere range that means Hetherington. Sturdy, good-looking switches —both push button, toggle, rotary, and other types—for unique operating or mounting requirements have long been a Hetherington specialty. Chances are, Hetherington switch engineers can recommend something out-of-the-ordinary that will enhance the appearance and saleability of your electrical products while assuring long, happy switch performance.

### NEW PUSH BUTTON SWITCHES FOR AVIATION'S TOUGHEST JOBS . . . *Designed to MIL-S-6743 Specs*

Designed to MIL-S-6743 drawing MS25089, these rugged, fully moisture-proofed snap action switches take a full 50 G shock and wide-amplitude vibrations up to 55 cps without contact transfer.

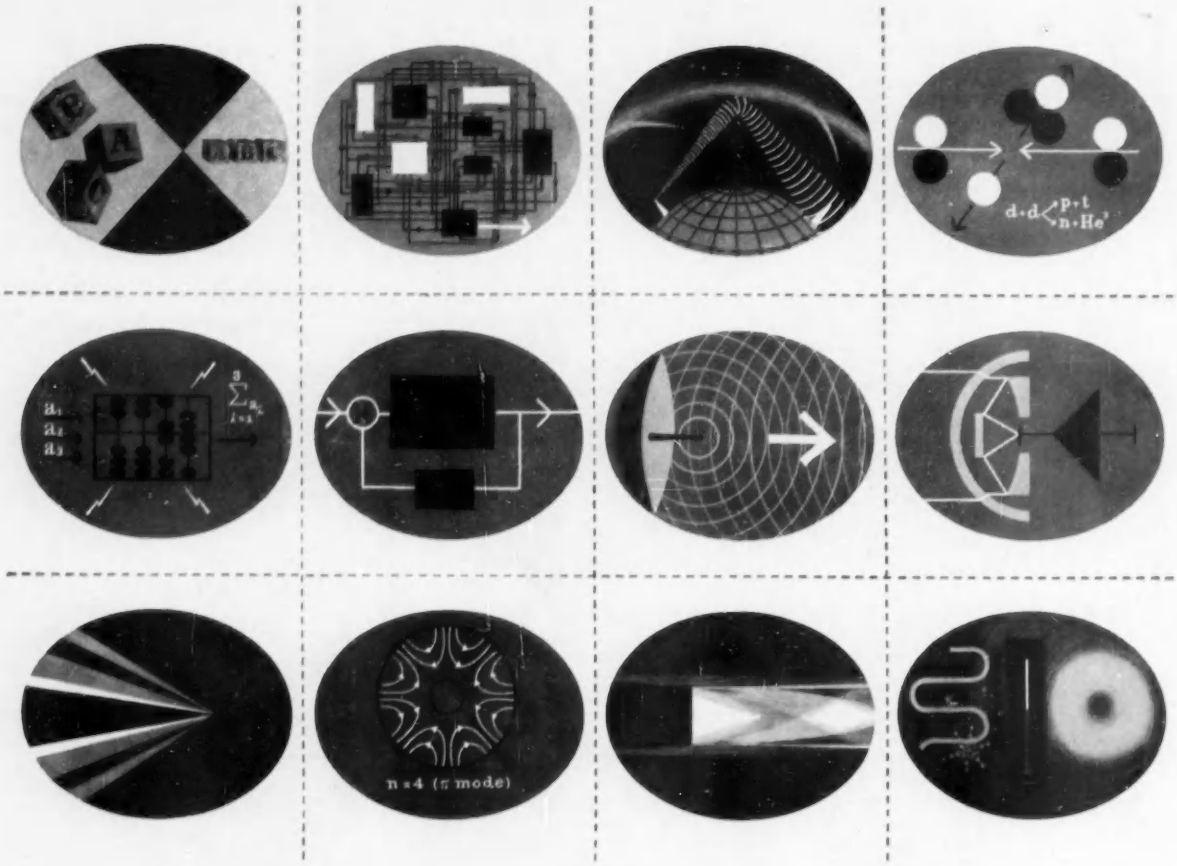
The basic switch can be fitted with any of eight different anodized aluminum mounting adapters, such as those illustrated, to meet virtually any mounting or design requirement.

Two-circuit, three-terminal, SPDT, and other contact arrangements are available with ratings up to 10 amps, 28 volts dc. Ask for details on Hetherington Series W100.

Similar switches for non-MIL and industrial applications are available in over 1800 different types as Hetherington Series "JR."

**HETHERINGTON INC.** 1200 ELMWOOD AVE., SHARON HILL, PA. • 139 Illinois St., El Segundo, Calif.

*designed for use where one failure is one too many*




# Variety of Technical Fields

These illustrations are symbolic of some of the scientific and engineering fields of endeavor which are essential ingredients in the broad range of technical programs that are in progress at The Ramo-Wooldridge Corporation. Illustrated are: Information Theory, Systems Analysis, Communications, Nuclear Physics, Electronic Computers, Servomechanisms, Electromagnetic Propagation, Infrared, Aerodynamics, Microwaves, Propulsion, and Thermodynamics.

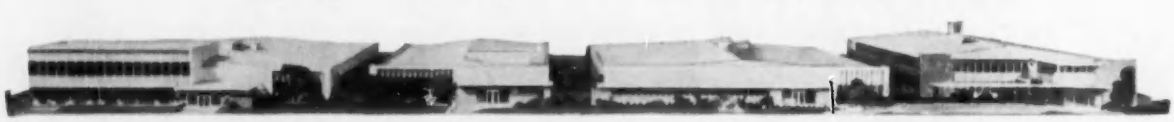
The requirement for technical competence in a wide variety of fields is a significant characteristic of systems engineering work. At R-W this requirement is particularly important because of our emphasis on the development of systems having a high content of scientific and engineering newness.

Our current military contracts support a number of advanced programs in the fields of modern communications, digital computing and data processing, fire control and navigation systems, instrumentation and test equipment. In the guided missile field, Ramo-Wooldridge has technical direction and systems engineering responsibility for the Air Force Intercontinental and Intermediate Range Ballistic Missiles. Our commercial contracts are in the fields of operations research, automation, and data processing. All of this work is strengthened by a supporting program of basic electronic and aeronautical research.

*Scientists and engineers whose training and experience are in these or related fields are invited to explore the openings at The Ramo-Wooldridge Corporation.*

## The Ramo-Wooldridge Corporation

5730 ARBOR VITAE STREET · LOS ANGELES 45, CALIFORNIA



# VIC HANSON **metes the need**

Down in Wilmington recently we asked some du Pont engineers how they liked our September '56 issue which defined the steps of control systems engineering (specify, design, test). "Why fine," we heard, "but you left out a step." "What was that?" we gulped. "Why," it came back solemnly, "the very first step—see Vic Hanson."

Later, sitting in his office in the company's Engineering Research Laboratory, we quickly realized why Vic Hanson is indeed the first step in many of du Pont's successful new ventures in automatic process control. "Before you even specify a system for a new process," advised Vic, "you've got to know what you want to measure—and then, after scanning the commercial equipment and known methods, you often have to find a new way to measure it. And sometimes this becomes the first major problem you must solve in engineering a control system or even in making the operation of a new process possible. Our Applied Physics Group is kept pretty busy developing the instruments to meet this need."

Victor F. Hanson has had a long career in meeting the needs of metering. In 1926, then 22, he was awarded a BS in Physics from Cal Tech and spent the next six years in Culver City developing geophysical instruments and electromechanical processes. Starting as a development engineer with du Pont in 1934, Vic moved steadily up the line to his present job as assistant director of ERL. Also under his guidance is du Pont's new $2-million Radiation Physics Lab. When the building is completed he'll take over on a full-time basis.

Right from the start Vic's work in du Pont's Niagara Falls Electrochemical Dept. opened his eyes to the tremendous potential for specialized measuring techniques in process control. Although faced with some skepticism from operating personnel, in 1936 he installed the first electronic on-stream measuring instrument to actually control a continuous process: a photometric chlorine analyzer (see picture, page 4) it has saved millions of pounds of this chemical per year and literally paid for itself in the first few minutes of operation.

Even with this spectacular success at Niagara Falls, prejudice continued in the plants against vacuum-tube type measurements. But Vic Hanson's progress in solving special measuring problems as superintendent of Hanford Engineer Works' Instrument Dept., during 1944 and '45, soon overcame the opposition. After establishing the Applied Physics Section in Wilmington in 1945, he was again involved in an atomic energy project—this time setting up the instrumentation development program for du Pont's huge Savannah River plant. Here, since the commercially available nuclear measuring instruments were inadequate, he focused his effort on the modification of these to meet the new requirements. And then Vic went to the makers and convinced them to add the changes to their standard products.

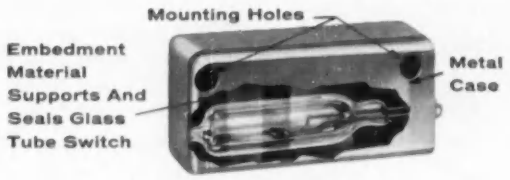
Looped by instruments, Hanson tells "how come" on page 79.

### *A transducer for exotic birds*

Vic Hanson carries his zeal for better measurement right into his recreation. One recent project: the development of high-speed equipment for photographing, in color, birds in flight. Armed with this equipment he recently ventured, along with his wife Dorothy and some friends, into the jungles of Ecuador for two weeks where he assisted in snapping native birds in their natural surroundings. When not afield picture taking, Vic likes to work on his 200-year-old house on a 250-acre farm at Yorklyn, Del. What does he raise? "One cat and one dog," admits Vic. "Now that our two boys are away (one in the Navy, the other at MIT)", he continues, "Dot is the really active one at home in our family. When she is not tied up in civic activities, I may get a glimpse of her between her searches for early American antiques."

# ...have uses unlimited

## MERCURY SWITCH accurate to ⅛ inch in 12 feet on grader




*(Send for Catalog 90-A—*
*"HONEYWELL Mercury Switches")*

Mercury switches are not usually associated with such applications as heavy road grading machinery. However, four of these protected HONEYWELL Mercury Switches have proved successful as grader blade controls.

Tilt action of the switches actuates a series of power relays and valves to control the grader blade. The switches are so sensitive that they are able to control the level of the blade within ⅛ of an inch in an overall movement of 12 feet. The switches—embedded in epoxy within a metal case—are extremely resistant to shock and exposure to the elements.


## MAXIMUM ACCURACY plus long-life performance

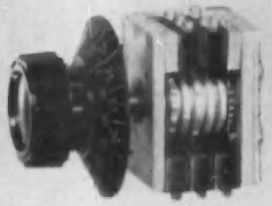
Switches used in woodworking production equipment—cut-off saws, rip saws, gang saws and jointers—must take a lot of punishment and retain maximum accuracy for a long life.

These enclosed switches, with roller arm actuator and sealed plunger, were chosen by designers as controls on an automatic air-operated cut-off saw. One switch controls the reversing of the solenoid for length of stroke. The other is a return control.

Both switches must operate with maximum accuracy and give long-life performance. At an average of 1,250 strokes per hour, the switches are activated 10,000 times in the average 8-hour work day.

*(Send for Catalog 83A—*
*"Industrial Enclosed Switches")*

## FIVE tiny switches permit 32 on-off situations



Five MICRO SWITCH subminiature switches were selected by design engineers in this rotary selector switch to provide the switching function for each of the pulse positions in a five-pulse binary code switch. Each switch is of single-pole, double-throw design, thus providing 32 on-off current combinations for data processing equipment.

The binary switch is a single control, positive locking, electro-mechanical device for converting rotary operation into a binary sequence.

According to the designers, the MICRO SWITCH subminiature switches were chosen because of:

1. Small size and light weight (¾ × ½ × ¼ inch)—(265 per pound).
2. Ease of operation.
3. Reliability.
4. Extremely low contact resistance (through use of fine silver).
5. Positive make and break action.
6. Resistance to shock and vibration.
7. Low capacitance between open contacts and from terminals to ground.

There is no limitation in the design as to the number of switches that can be used.

*(Send for Catalog 75A—"Subminiature Switches")*

**MICRO SWITCH**

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS

# kepco

# VOLTAGE REGULATED POWER SUPPLIES

*for powering electronic equipment*

## KR SERIES

with ***NEW-IMPROVED FEATURES***

★ ***FAST*** RECOVERY TIME

★ ***GOOD*** STABILITY

★ ***LOW*** OUTPUT IMPEDANCE

**KR Voltage Regulated Power Supplies are conservatively rated and are designed for continuous duty at 50°C ambient.**

**REGULATION:** Less than 0.2 volts for line fluctuation from 105-125 volts and less than 0.2 volts for load variation from 0 to maximum current.

**RIPPLE:** Less than 3 mv. rms.

**STABILITY:** The output voltage variation is less than the regulation specification for a period of 8 hours.

**RECOVERY TIME:** Less than 50 microseconds. The excursion in the output voltage during the recovery period is less than the regulation specification.

**OUTPUT IMPEDANCE:** Less than 0.1 ohms from 20 cycles to 100KC. Less than 0.5 ohms from DC to 20 cycles. Many units have very much lower output impedance.

KR-3M

KR-18MC

***FEATURES:***

- Fast Recovery Time, Suitable for Square Wave Pulsed Loading.
- Voltage Range continuously variable without Switching.
- Either Positive or Negative may be Grounded.
- Oil Filled Condensers.
- Wire Harness and Resistor Board Construction.
- Power Requirements 105-125 volts, 50-60 cycles.
- Terminations on rear of unit.
- Locking type voltage control AC, DC Switches, Fuses, and Pilot Lights.
- Color Grey Hammertone.
- Guarantee One Year.

**All models available for 400 cycle operation on special order.**

### 1.5 Amp. KR SERIES

| Model | Volts | 6.3V AC | Rack Mount W | H | D | Price |
|---|---|---|---|---|---|---|
| KR16 | 0-150 | Each supply | 19" | 12¼" | 17" | $625 |
| KR17 | 100-200 | has two | 19" | 12¼" | 17" | $625 |
| KR18 | 195-325 | 15 Amp. | 19" | 12¼" | 17" | $695 |
| KR19 | 295-450 | outputs | 19" | 12¼" | 17" | $695 |

### 600 ma. KR SERIES

| Model | Volts | 6.3V AC | Rack Mount W | H | D | Price |
|---|---|---|---|---|---|---|
| KR 8 | 0-150 | Each supply | 19" | 10½" | 13" | $330 |
| KR 5 | 100-200 | has two | 19" | 10½" | 13" | $240 |
| KR 6 | 195-325 | 10 Amp. | 19" | 10½" | 13" | $240 |
| KR 7 | 295-450 | outputs | 19" | 10½" | 13" | $250 |

### 300 ma. KR SERIES

| Model | Volts | 6.3V AC | Rack Mount W | H | D | Price |
|---|---|---|---|---|---|---|
| KR 12 | 0-150 | Each supply | 19" | 7" | 11" | $270 |
| KR 3 | 100-200 | has two | 19" | 7" | 11" | $180 |
| KR 4 | 195-325 | 5 Amp. | 19" | 7" | 11" | $180 |
| KR 10 | 295-450 | outputs | 19" | 7" | 11" | $190 |

### 125 ma. KR SERIES

| Model | Volts | 6.3V AC | Rack Mount W | H | D | Price |
|---|---|---|---|---|---|---|
| KR 11 | 0-150 | Each supply | 19" | 7" | 11" | $180 |
| KR 1 | 100-200 | has one | 19" | 7" | 7½" | $ 90 |
| KR 2 | 195-325 | 3 Amp. | 19" | 7" | 7½" | $ 90 |
| KR 9 | 295-450 | output | 19" | 7" | 7½" | $ 97 |

To include 3" Current and Voltage Meters, Add M to Model number (e.g. KR 16-M) and Add $30.00 to the Price.
To include Dust Cover and Handles for Table Mounting, Add C to Model number (e.g. KR16-C) and Add $10.00 to the Price.
To include Meters, Dust Cover and Handles, Add MC to Model number (e.g. KR-16 MC) and Add $40.00 to the Price.

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## WHAT'S NEW

### INTO A TENT IN L. A.

Over 30,000 engineers crowded through the flaps of the tent pictured on the right during Aug. 21-24. The occasion: the 1956 Western Electronic Show and Convention—cosponsored by the California Sections of IRE and WCEMA. Like its eastern counterpart, the annual IRE show in New York, WESCON grows more vital to control engineers each year. Special note: while the 711 exhibits and 48 sessions were obviously defense-oriented, a distinct industrial flavor seasoned the conclave.


### UP AN ESCALATOR IN N. Y.

An unprecedented 36,186 engineers and instrument technicians rode up the escalator pictured in the right at least one time during Sept. 17-21. They were on their way up to the second deck of the handsome new Coliseum—and to half of the 450 exhibits of industrial automatic control equipment gathered by ISA for its 11th Annual Conference and Exhibit. Special note: in the 100 papers and three superb clinics the visitors got an excellent briefing on progress in the past year.

Both of these huge technical gatherings are prime examples of how equipment makers and societies can pool their efforts in . . .

# Meeting the Needs of Control Engineers

Within the short period of one recent lunar month over 60,000 engineers who have, or hope to have, something to do with the design and/or application of instrument and control systems, left their jobs and flooded like the tide to opposite shores of our land for a week of looking at new products and learning about new techniques in control.

What did these pilgrims to WESCON and the ISA Show hope to find at these conclaves? Did they go away rewarded?

CONTROL ENGINEERING'S editors joined the tide sweeping west and then east—first to Los Angeles tent-annexed Pan Pacific Auditorium, then to New York's bright new Coliseum. As reporters they perhaps had more interest than the average visitor in any and all new items and thoughtful papers. But even they had an eye out for particular developments—

- at WESCON—new devices and techniques spawned by defense but with intriguing industrial potential
- at ISA—new devices and techniques spawned by industry but with intriguing defense systems potential
- at BOTH—advances in product and in theory which reflect the growing use of control engineering principles across the field

Our show-going editors suffered only minor disappointments. At WESCON they had to shuffle through hundreds of booths where electronic components and black boxes with control-system "appeal" were unmarked or undramatized for their end use. But they report glowingly on the high quality of the technical papers and keen attendance at the control sessions. At ISA their enthusiasm for the equipment exhibits is unmitigated. "Throw a stone," they say, "and you'd hit a new, handsomely displayed product for control." They found the ISA technical sessions, too, beautifully planned and broad in scope, but they were often disturbed by the lackluster questions in the meeting rooms when talks ventured into more technical areas.

Aside from these minor shortcomings, say the editors, both conclaves went a long way toward satisfying the needs of control engineers. In the next 15 pages and in special portions of the *New Products* and *Abstracts* sections (pp. 136 and 194), they tell why.

FOR A GUIDED TOUR
OF THE CONCLAVES

# Highlights from

WESCON: DISPLAYS indicated a growing awareness of the need to show product function, but the large majority of exhibitors still buried control items in a maze of communications products. The booths were attractive though—many new displays were created just for this show. Missiles and related working systems got the biggest crowds. And our visitors report a lot of industrially-hepped people manning the booths.

**WESCON: SESSIONS** included many advanced papers in control theory, were generally well-attended. Pictured above are members of a panel on education—moderated by McGraw-Hill's George Tenney. Profs. Terman and Martin (Stanford and Arizona) gave the school viewpoint, and Noble and Dempster (Motorola and Electronic Engineering Co.) held forth for industry. See page 34 for more on the sessions.


**WESCON: SHOW STEALER** was the first public display of Convair's TERRIER guided missile. Our cameraman had to wait for a lull in the show to take this shot—the booth was always jammed. This is understandable: almost all the innards of TERRIER involve electronic control hardware—much of it furnished on contract by Los Angeles area firms. See page 30 for more WESCON show-stealers.

**WESCON: DEMONSTRATIONS** often took place in the more easy-going atmosphere of a hotel suite. Shown above is the Sylvania pitch in the Mission Room of the Statler Hotel on its new WAMOSCOPE microwave display tube. There were no special workshops or clinics at WESCON.

**WESCON: CONVIVIALITY** came to a head at the All-Industry Luncheon—a complete sell-out at the Cocoanut Grove. Dr. W. Baker of GE gave the keynote address. Highlight for the ladies was an aquatic festival in the Ambassador pool.

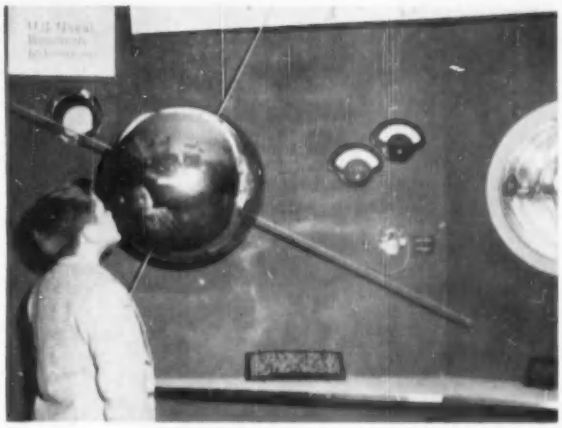
CONCAVE REPORT CONTINUES ON PAGE 28 ➔

# the Conclaves

ISA: DISPLAYS were remarkable for their sophistication and showmanship. One major exhibitor offered an impressive seven-station booth tour. Another had a double-deck display. Still another isolated his products on stark, individual metal racks. Booth attendants were smart—there was usually a man on hand who knew the answer. And the giveaway literature was brightly voluminous—but rather short on engineering data.

ISA: SESSIONS were mainly practical expositions on progress in industrial control. Pictured below is Prof. Don Eckman (Case Institute) describing the methods which must be followed in order to integrate a computer into an industrial process control system. Don's paper was the highlight of an excellent all-day symposium on computers. See page 34 for more on the sessions.

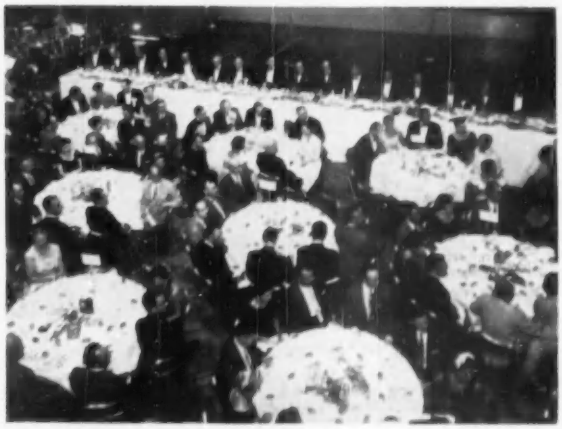
ISA: SHOW-STEALER was the first public display of the Naval Research Lab's full-scale model of the earth-satellite—including its newly revealed instrument innards. That's Managing Editor Lloyd Slater's son Pete inspecting an optical sensor in the "moon". Thousands flocked to this display. See page 32 for more ISA show-stealers.



ISA: DEMONSTRATIONS were all in carefully planned clinics and workshops arranged by society committees. Below is a valve demonstration in the Maintenance Clinic—one of 24 workbench sessions. Other shirtsleeve clinics covered five types of product analyzers; there was also a workshop on data handling. See page 38 for more on the clinics.

ISA: CONVIVIALITY was highlighted by the Society Banquet at the Statler. Along the head table are ISA officers (who unfortunately had too much to say). A right smart floor show, featuring the "Automation Blues", rounded out the evening.

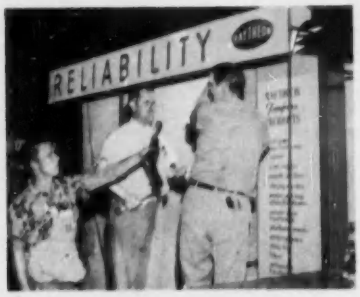
CONCLAVE REPORT CONTINUES ON PAGE 28 ➔



# WHAT THE WESCON–ISA DISPLAYS STRESSED

**After several days of trudging the aisles and looking for products that attracted the most interest—as well as reflected the most activity on the part of development engineers—our reporters pinpointed the items below.**

## 1. WESCON




RELIABILITY proved to be the most important quality in many WESCON displays. Raytheon, for example, set up its backdrop to focus on this virtue. Three complete sessions, including 13 detailed papers, dealt with this subject—a good share of them directed at the vacuum tube. The exhibition booths also held a large variety of reliability test equipment.


DIGITAL TECHNIQUES seemed to be spreading tentacle-like into many interesting areas at WESCON. Electronic Control Systems displayed an item unusual for an electronics show: a sturdy, ultra-mechanical milling machine sat in its booth. The reason: to show off the company's digital control system (which also applies to lathes and borers). For other digital displays see page 30.


MISSILE GUIDANCE was featured in major or minor fashion in at least eight booths at WESCON. The Autonetics Div. of North American Aviation gave over its whole display to its system for inertial navigation. Others with displays in this field: Bendix Aviation, Burroughs Corp., Collins Radio, Convair, Ford Instrument, GE, Kearfoot, Minneapolis-Honeywell, Sperry Gyroscope.

## 2. ISA

SYSTEMS in "package" form and for specific industrial applications were emphasized in dozens of ISA booths. The temperature logger shown above is typical. It's an automatic multipoint scanning system developed by Hot Spot Detector Co. for large grain and food storage facilities. Cable-thermocouples are part of the system. For views of three more systems shown in ISA booths, turn to page 32.

ACTUATORS apparently have been a subject of urgent development over the past year. Seen above is Conoflow's new all-electric valve actuator for proportional control systems. It offers 4-in.-per-min stroke at 500-lb thrust and typifies how valve makers are meeting the challenge posed by faster electronic controllers (see *Pulse*, page 71). Three new electrohydraulic actuators were also shown.

IN-STREAM ANALYZERS were at the show in abundance. The unit above (being diddled with by Associate Editor Harry Karp) is a new chromatographic analyzer. Developed by Carbide & Carbon instrument engineers, it is being made by Watts Mfg. Co. At least a half-dozen other new analyzers were shown which originated in the labs of users. For a report on analyzer clinics, turn to page 38.

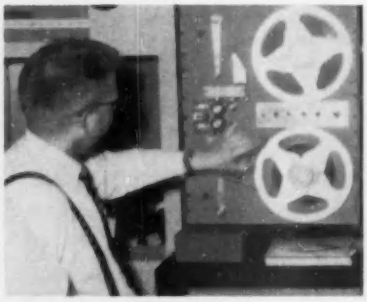
# MORE SHOW STEALERS AT WESCON

**On page 26, which covers WESCON highlights, the booth-jamming Convair TERRIER was pictured as a "show stealer". But there were many other items that drew big crowds at the show. A few are grouped below.**

## INFORMATION HANDLERS WERE EVERYWHERE


**HALL SCOTT ELECTRONICS** placed its new 20-amplifier desktop analog computer on view. The unit has many plug-in features: input and feedback elements, function generator, etc. It can solve seventh-order linear differential equations.

**ELECTRONIC ENGINEERING CO.** revealed part of its $3-million centralized data-processing systems (PROJECT DATUM) which it is delivering to Edwards AFB. The system hunts and selects, on command, any item in its 14-track reel.



**KEY ELECTRIC CORP.** proudly unveiled its new digital magnetic-tape handler. It can start and stop within 5 millisec, can speed a ½-in. tape through 15 in. within 30 sec, and is equipped with a servo reel drive exerting only 1½-oz. tension.

## WORKING SYSTEMS TOLD THEIR OWN STORY


**HYCON EASTERN,** with its working model of a scatter transmission system, neatly proved how radio waves can be bounced off the ionosphere to get beyond-seventh-order linear differential equations. says it approaches 99.95% reliability.

**THE GUDEMAN CO.** put its linear variable differential transformer to work measuring the deflection of a heavy rail. Newly available, these transformers can measure mechanical motion as small as 0.00002 in. and produce a 1-millivolt output.

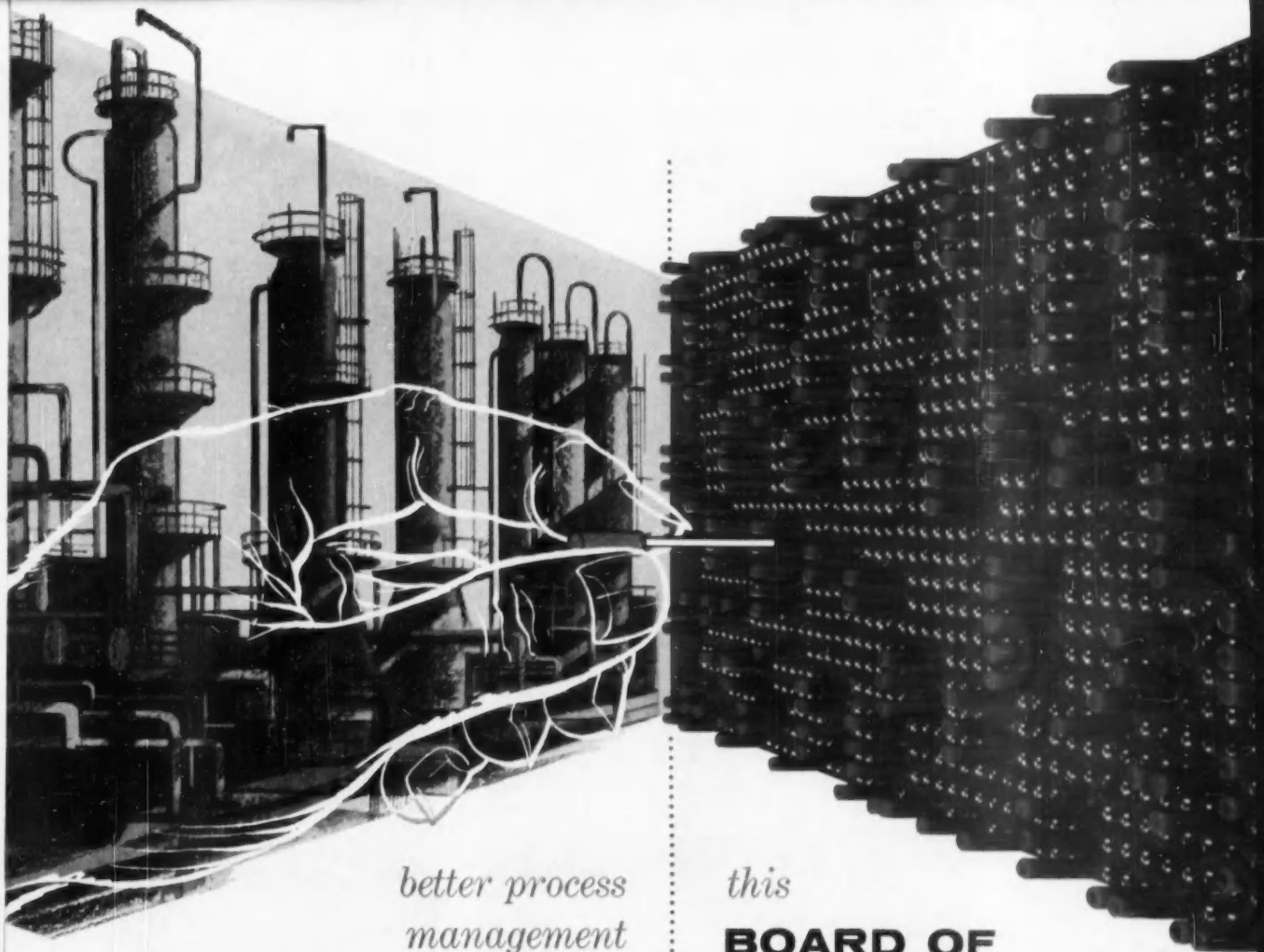
**TEXAS INSTRUMENTS** demonstrated the use of its transistors by passing a HO-gage model train through a control beam. One of the company's "grown-diffused", very-high-frequency germanium transistors did the job operating at 200 megacycles.

## BOOTH BEDAZZLERS: Thunderbirds, Falcons, and Zoots


**HELIPOT** bedecked its booth attendants with colorful jackets to lure the passing throngs. Once in the booth, though, guests were given a mighty serious pitch on pots and their potential. The "canned" spiel also drew them in.

**HUGHES PRODUCTS** drew big crowds around its FALCON. And when they looked behind the missile they were sure to see (in the black wall mounting) the company's new "Tonotron" storage tube that, claims Hughes, "reads like a map".

**FEDERAL TELEPHONE & RADIO CO.** pulled them in with an operating two-way mobile radio installed in a pint-sized Ford Thunderbird. Once inside the booth, they saw the company's new 3-D flux meter and portable field strength indicator.



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*"Magnetic core logic" – "floating" – semiconductor circuitry.* Although these features in the "112" are of primary interest to the technical man, to the top executive they mean round-the-clock, round-the-calendar accuracy and reliability–data you can depend on, all the time. For complete information, write Beckman Instruments, Inc., Data and Control Systems Dept., Fullerton, Calif. Ask for Data File D-2-46.

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*Beckman "112" Data System, with exclusive "Pinboard Programmer".*

**Beckman** / *scientific instruments*

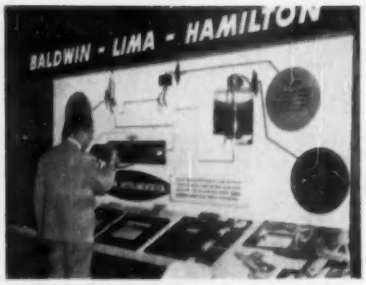
# MORE SHOW STEALERS AT ISA

**On page 27, which discloses some of the ISA highlights, the shiny model of the earth-satellite was shown as the "show stealer". But, as the views below indicate, there were many other items that drew crowds into the booths.**

## CLOSED LOOPS IN ACTION

**BECKMAN** pulled crowds with a handsome guided-tour display that traced the development of an "automatic plant" from design through measurement to computer control. Seen above is the "process" which was hooked into a working EDP system.

**RELIANCE ELECTRIC & ENGINEERING** intrigued the passing process control engineers with its versatile working display of "dynamic response" motor control in action on a continuous flow application. To many this proved a new concept in flow control.




**BALDWIN-LIMA-HAMILTON** drew them in with an elaborate working setup which showed how strain gage transducers cope with such variables as flow, weight, and pressure. Visitors could fiddle and select, and results were inked out on recorders below.

## PRODUCT ANALYZERS HAD A HEYDAY


**FIELDEN** booth people were kept on their toes putting the neat little continuous moisture analyzer, shown above, through its paces. Originally developed by Quaker Oats for grain, the unit is rigged up to control fuel to a product dryer.

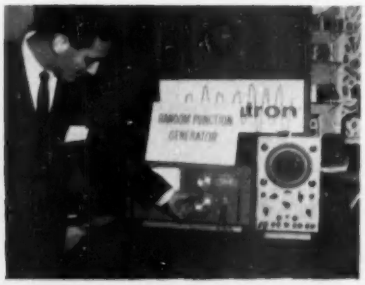
**BARNES ENGINEERING** always had a group around its new process stream refractometer. Simple and compact, the sampling chamber (below) handles up to 0.25 gpm and the unit is sensitive to index changes as small as 0.000002.

**OHMART** had many visitors poring over a new horizontal measuring assembly for its standard radiation-type continuous liquid density gage. In effect, the unit furnishes a 14-in. product sample in a simple 3-in. pipe section.

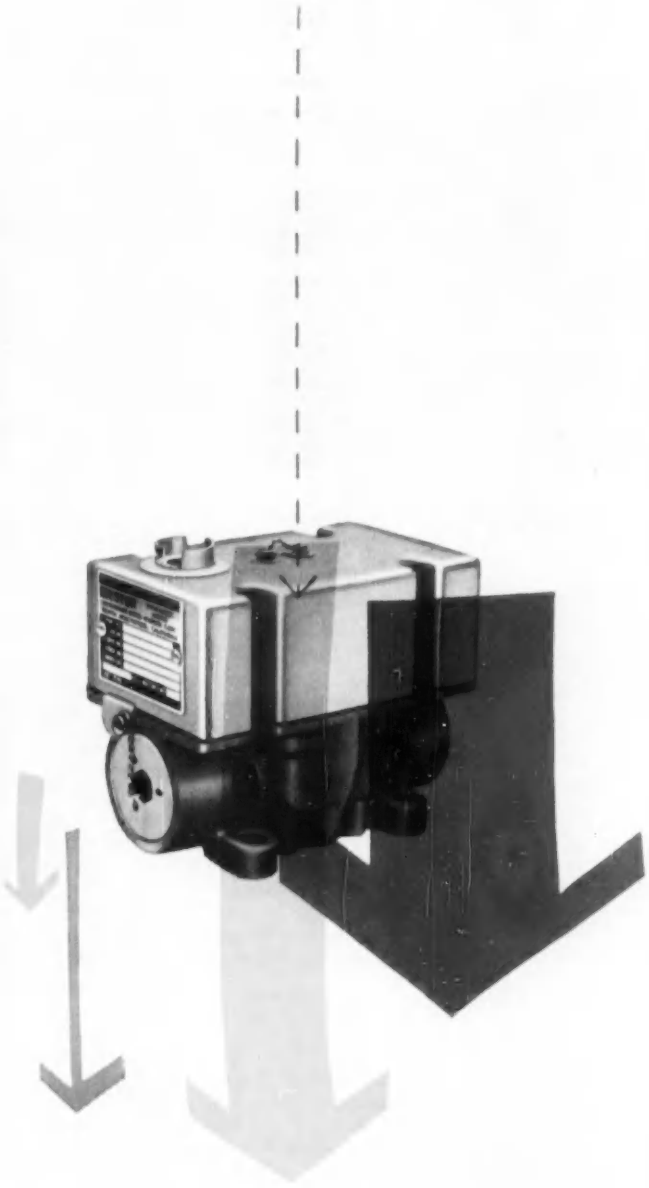
## THREE DEVELOPMENTS WELL WORTH NOTING

**SOUTHWESTERN INDUSTRIAL ELECTRONICS** treated flow measurement, in its working display, from orifice to office. Its system computes gas flow through pipe, integrates rate and volume, and flashes results to a distant logger.

**MINNEAPOLIS-HONEYWELL** got big interest with its new line of high-pressure valves. Who wouldn't be interested in the fact that missile engineers had to go to an industrial valve maker for proper hardware in loading fuel systems?



**INTERCONTINENTAL DYNAMICS** had to spend time explaining how its new random function generator will help control engineers (i.e., statistical analysis in closed-loop systems). But when it "came across", the interest was far from random.



## an important entry into an important field

**A NEW DRY COIL, DUAL STAGE ELECTRO-HYDRAULIC SERVO VALVE...** Over two years in development ...now ready to perform critical tasks in the control of piloted aircraft and guided missiles. Designed to achieve greatest possible reliability, a mechanical force feedback system between stages, together with a frictionless hydraulic seal, provides extreme sensitivity without the necessity for dither. Your inquiries on specific applications are invited.

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## WHAT'S NEW

### WHAT THE WESCON-ISA SESSIONS STRESSED

**Away from the exhibit floor the visiting engineer had a chance to rest his feet and activate his own personal input devices in one or several of the technical sessions. The editors report below on the fidelity and "noise" in the data that was transmitted.**

### 1. WESCON:

"Of interest to control engineers," writes Consulting Editor Gene Grabbe (who also chairmanned a session on control mechanisms), "were several sessions sponsored by the IRE Professional Groups on Automatic Control, Computers, and Circuit Theory. Subjects ranged from advanced control techniques to practical applications of control systems. For example, at one Automatic Control session, over 400 engineers heard of new developments in statistical theory as applied to control systems. C. W. Steeg of MIT in his "A Time-Domain Synthesis for Optimum Extrapolators" described a way to arrive at the optimum filter for a control system which circumvents the practical difficulties encountered in design of optimum predictors based on the Wiener theory. R. M. Stewart of the Jet Propulsion Laboratory also discussed application of Wiener's least square filter theory to missile control.

"A radically new approach to measurement was revealed in "The Eye as a Control Mechanism" by Robert B. Lockard in a second session on automatic control. An experimental tracking system was built in which the human eye movement was used to provide the error correction signal for positioning control. Such a system could furnish trajectory data in real time, and under proper conditions would have a much higher accuracy than ordinary tracking systems now in use.

"Four computer sessions were concerned with techniques, design, and equipment. Sessions on transistor circuitry literally overflowed. During one of the latter, R. H. Baker of Lincoln Laboratory told of new transistor circuits with special potential for control applications. Using this new approach, flip-flops, converters, and gates can be built to operate at high frequencies (up to 12 megacycles) with power dissipations of only a few milliwatts. This significant development should lead to more compact, lower power equipment. The circuitry is not sensitive to components and should permit more design freedom than has been possible with tubes or ordinary transistors."

### 2. ISA:

"The ISA technical sessions," writes Lloyd Slater, "covered an astounding range of subjects—from aeronautical and biological instrumentation through computers and data handling into human engineering and nuclear control and transportation and testing. From the control theory standpoint, the most rewarding papers were offered in two sessions run by the Instruments & Regulators Div. of ASME (see CtE, October 1956, pp. 164-165, for abstracts). Also noteworthy in this area: three papers

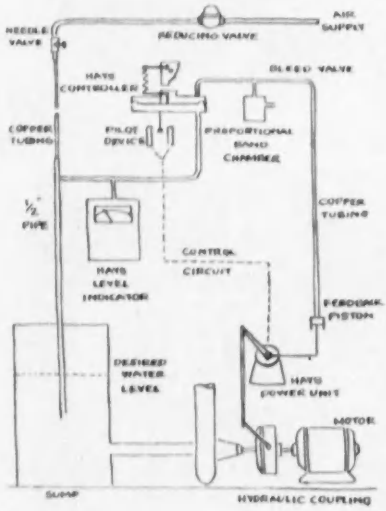
**KICK-OFF SESSION**

**Both WESCON and ISA led off with a big general session on IGY and the earth satellite. Shown is the ISA opener, which was followed by two days of sessions on IGY instrumentation.**

# RAMBLINGS ON INSTRUMENTATION

## Liquid level control—a simple solution

Interesting (and profitable) results occur when instrument engineers start thinking about power industry-styled "draft gages" as *low pressure instruments*. Case in point is the system ("doodled" below) worked out by Hays' Denver representative, Joy & Cox, Inc.




The problem: To automatically maintain the liquid portion of wood pulp at a desired level by changing the speed of the pump withdrawing the liquid. A complicating factor was that liquid entered the sump from several sources and in variable quantities. Solution uses low pressure as an analog of level; any variance in pressure is sensed and indicated by a Hays diaphragm-operated indicating gage. A Hays diaphragm-type constant pressure controller electrically regulates the speed of the centrifugal sand pump and, thus, the level. Voila! a levelled sump.

 or  ?

With the trend toward smaller panel boards, we're getting more calls for miniature analog indicators. Customers seem to fall either into the "circular" or "vertical" schools of preference. Fortunately, our Hays Division offers the Model RERFI circular indicator in 4½", 6", and 8½" 270° *circular* scales as well as the Model M *vertical* gage with a 5" usable scale.

## That carbon shall rise again . . . and again . . . and again

Not long ago, engineers at Corn Products Refining Company discovered that they could save substantial wampum by using carbon instead of bone char for the removal of color from dextrose liquids—*if* they could reactivate it effectively for repetitive use. Too little $O_2$ would give incomplete reactivation and too much $O_2$ would cause uncontrolled ignition and, hence, loss of carbon and kiln damage.

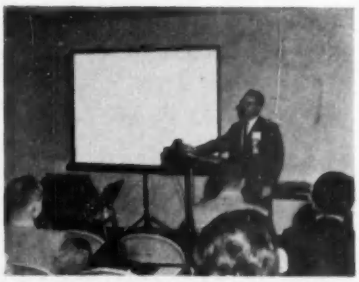
Hays $O_2$ Analyzers and Recorders, complete with filter-aspirator sampling systems, were installed in order that operators could adjust the incoming steam and air (at 1800° F.) to hold $O_2$ content of the kilns at the correct level. The lush box score on this scheme reads as follows: 12-fold increase in color removing capacity; Hays $O_2$ equipment paid for itself several times over in less than two years; low maintenance cost on kilns (no downtime since start up). Complete detail on the above items is yours for a 2c post card.

Phil Sprague Jr.

Executive Vice President

THE HAYS CORPORATION/THE METROTYPE CORPORATION · MICHIGAN CITY, INDIANA

## WHAT'S NEW



**MEDICAL INSTRUMENTATION was covered in one WESCON, four ISA sessions. Seen above is Dr. Arthur MacNeill telling his ISA audience about, among other things, an automatically-controlled blood-pump dializer that will remove surplus water from body tissues.**

in the production-process control sessions on dynamic analysis techniques in the study of a chemical reactor, a fractionating column, and a heat exchanger. (See abstract of paper by Batke, Franks and James).

"Strongest emphasis in the technical program was given to analysis instrumentation: there were eight sessions (27 individual papers) on new and improved ways to measure product in-stream. Many of these papers were presented by users who had developed new units over the past few years. Others were by users who had tested out a new measuring technique. One excellent paper by Mraz and Sanders of du Pont described how dynamic analysis was applied to an infrared composition control system.

"But it seems to me that the real theme of the ISA technical program was borne out in its four sessions on what it calls 'Instrumentation for Production Processes'. Here users from the paper, metal-fabricating, nuclear, chemical, petroleum, and food fields described how they had applied some of the advanced techniques of control engineering in solving in-plant problems in the past year. In other words, the theme of the meeting—despite many papers that were inclined to describe the 'nifty features' of new hardware—was one of practical progress *at the user level* in instrumentation and automatic control. Many people consider this growing emphasis in the ISA program a 'strong sign of a maturing technical society'."

Ed. note: Lloyd's comments above and Harry Karp's abstracts starting on page 194 comprise only Part I of our coverage of ISA's excellent program. Look for a report on the education session in next month's issue.

(Conclave report continues on page 38)

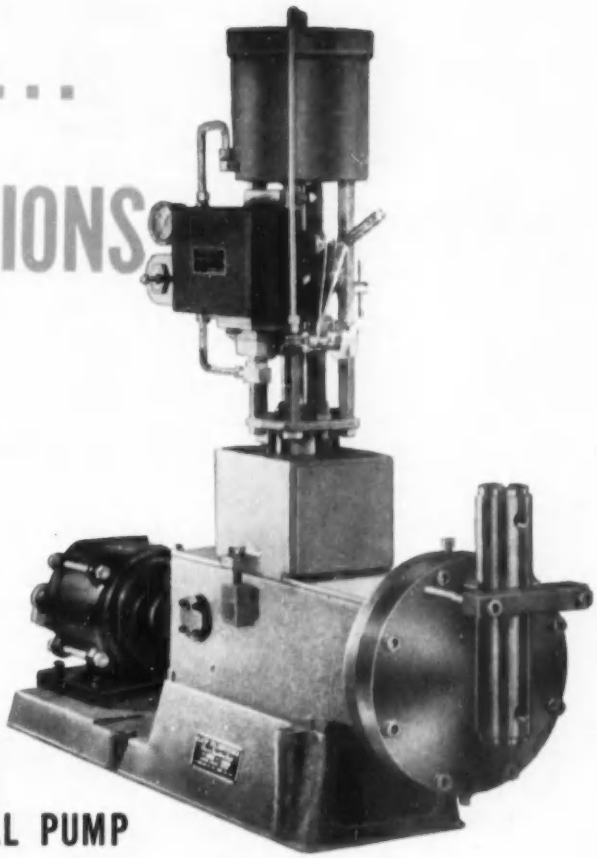
# IT PUMPS...

# IT METERS...

# IT PROPORTIONS

# IT FEEDS...

**WITHOUT LEAKAGE OR CONTAMINATION**



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**WRITE FOR BULLETIN 440** *with typical applications, flow charts, description and specification of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 703 Wilson Street, Le Roy, N. Y.*

**Lapp**

## WHAT THE ISA CLINICS COVERED

### 1. DATA HANDLING:

Reports Gene Grabbe: "This was a very stimulating workshop and attracted a sell-out crowd of 700 (only 200 were expected) to the various ballrooms of the Hotel New Yorker on Sept. 17-18. It was directed primarily toward an informal exchange of information on data-handling techniques and its formal papers were published and circulated in advance. The range of interest ran from aircraft and missile test through chemical processing to geophysical and medical data reduction.

"In the general session on the 17th eight panel members made short statements, then the audience dug in with reactions and questions. A lively session indeed—and everyone stayed. The sessions on the 18th were organized in horizontal and vertical fashion by subject matter. 'Stimulators' headed these sessions—and successfully activated audience discussion of needs, problems, and solutions. Once again, attendees were unanimously enthusiastic about the results and asked for more of the same.

"More experimentation of this type is needed—as CtE has frequently pointed out in editorials—to avoid the dullness and lack of exchange that plague most technical sessions. Don Prell of Benson Lehner, the guiding hand behind the workshop, is to be congratulated for his fine job of organizing and coordinating the session."

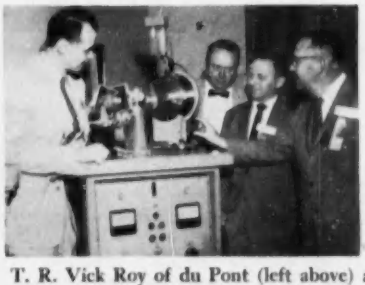
### 2. ANALYTICAL INSTRUMENTS:

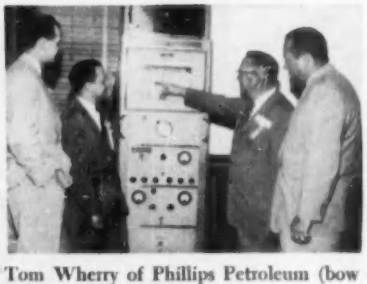
Reports Harry Karp: "It was quite an experience to roam through rooms on the first and second mezzanine of the Statler Hotel on Sept. 20 and see engineers hunched over and around process analyzers (see pictures below). It was all part of the two-day clinic run by ISA which gave process control engineers a chance to get well-acquainted with the innards and application of five types of product analyzers. More than 300 came to the sessions, which were repeated four times to give every man a seat at them all. Incidentally, the techniques covered were pH, infrared, x-ray spectroscopy, thermal conductivity gas analysis, and gas chromatography. Frankly, I think this a splendid way for makers to expose user engineers to technical information about their new units—rather than by loading into the general sessions."

(*ISA clinics continue on page* 40)

Perkin Elmer's Vapor Fractometer

L & N's Continuous Infrared Analyzer





T. R. Vick Roy of du Pont (left above) and Tom Wherry of Phillips Petroleum (bow tie) lisen to North American Phillips x-ray spectroscopy demonstration.

# Millions of strokes

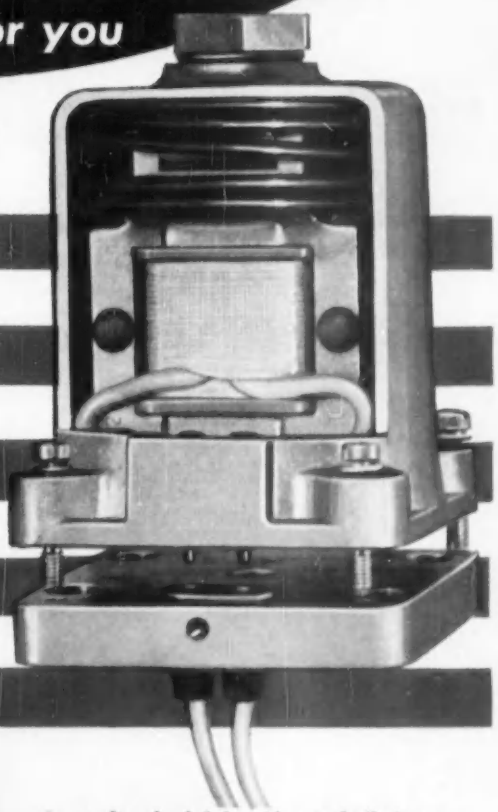
(at 300 strokes per minute)

# —NO MEASURABLE WEAR!

*that's how Decco's New Oil-Immersed Solenoid can perform for you*

**Decco's OIL-IMMERSED solenoid is so superior in performance and dependability, it is in a class by itself. Here are some of its outstanding features:**

1. Individually sealed in oil. No oil contamination.
2. Unbelievably little wear.
3. Efficiency increased. Power loss cut to amazing new low.
4. Operates 35° to 50° cooler than standard types.
5. Built with best mechanical features of Decco Standard Solenoids.
6. Solenoid is completely sealed in compact, die-cast housing.
7. Solenoid plugs into built-in receptacle in base. Easy to change.
8. Shock-mounted in two directions.
9. Built and tested to comply completely with J.I.C. specifications.



**Decco SOLENOIDS**

**Decco Standard Solenoids are built in a complete range of sizes and types. Write for complete information.**

**DETROIT COIL COMPANY**

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### 3. MAINTENANCE CLINIC:

ISA's popular Maintenance Clinic was held this year in laboratory classrooms of Columbia University. The pictures below show the kind of equipment the technicians and engineers worked on: 21 companies furnished products and instructors, and items ran from pressure regulators through computing relays to electronic controllers. Ed. note: Still another good example of ISA's well-organized and impartial method of getting the makers together with the users.

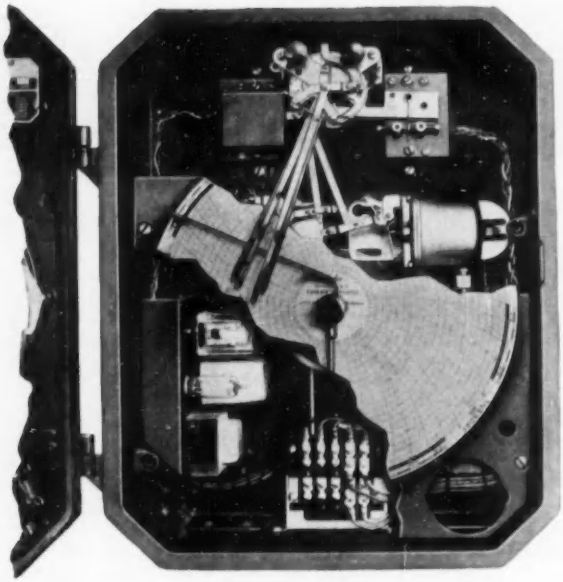
Foxboro's Dynalog

Hay's Magotherm

Honeywell's Teloset

Taylor's Miniature Recorder

# NEW ELECTRONIC CONTACT CONTROLLER BY *Taylor*



## FEATURES

- Changing Resistor-Capacitor Can gives Single Point or Differential Control. Control point easily adjusted by set pointer.
- Fully adjustable, self-locking differential between high and low contacts. Safe contact voltage—never over 6 volts. Current in micro-amps.
- Self-wiping control contacts made of non-corrosive Monel. All other parts are hermetically sealed against corrosion.
- Electronic tube, Relay and R-C Can are plug-in units. Load Contacts on Relay are Single-pole double-throw.
- Attachments can be fitted to present 100 Series Taylor Instruments with no drilling.
- Internal wires and external connections numbered for easy servicing. Signal lights and vibration damping available.

HERE'S rugged, positive contact action for control mechanisms of the two-position action type—the "on-offs", "open-shuts" and "high-lows". This new Taylor Electronic Contact Controller embodies a completely new concept in contact mechanisms—it's designed for:

1. Accurate and dependable operation of electrical circuits.

2. On-off applications with small process lags, slow reaction rates, and small and infrequent load changes.

3. Use on nearly all types of measuring systems—temperature, pressure, liquid level, flow, humidity, speed, etc.

4. Indicating, recording and/or controlling purposes. An extremely versatile instrument, the new Taylor Electronic Contact Controller can be used in many different places where pneumatic facilities aren't advisable or available. It's made also for use as a supplement to pneumatic control.

These standard forms emphasize the flexibility of the instrument: Two-Position Single Point Action (On-Off), Two Position Differential-Gap Action (On-Off with adjustable differential gap or neutral zone), and Three-Position Differential Gap Action (High-Medium-Low, differential adjustable).

For full details ask your Taylor Field Engineer or write for **Bulletin 98265.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

*Taylor Instruments*
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY

## WHAT'S NEW


R. W. Boesel


T. O. Moore


Irven Travis


R. A. Lamm


R. R. Kesti


C. D. W. Thornton


Gerhard Reethof


Michael Montalbano


G. L. Broomell Jr.

### Important Moves by Key People

▶ Among the projects that **Robert W. Boesel** will oversee as chief project engineer for Republic Aviation's Guided Missiles Div. are an air-to-air missile system and an air-to-surface firing control system. To handle these and other assignments, Republic recently moved its division into larger quarters in Farmingdale, N. Y., and created Boesel's post. Well-equipped academically as an engineer-supervisor (he has a masters in aeronautical engineering and one in business administration), Boesel also has solid field experience: he was with Bell Aircraft as project manager of a bomber defense missile system, with the Air Force as a meteorologist and flight instrument researcher, and with Stanley Aviation.

▶ **Thomas O. Moore**, the new chief electronic engineer of ORRadio Industries, Inc., maker of magnetic recording tape, has done extensive work in nuclear power applications, including the Navy-AEC atomic submarine project, and in recorders and recording systems. At ORRadio he will head the division that is developing and evaluating the new Irish instrumentation tapes (geophysical tape, computer tape for electronic computers, and an instrumentation tape that records both sound and color pictures for TV and the screen).

▶ **Raymond G. Bower**, who retired in September as vice-president of engineering of Burroughs Corp., has been succeeded by **Dr. Irven Travis**, vice-president of research since 1952. Travis, who becomes vice-president of

# RIGHT ARM
## of industrial research

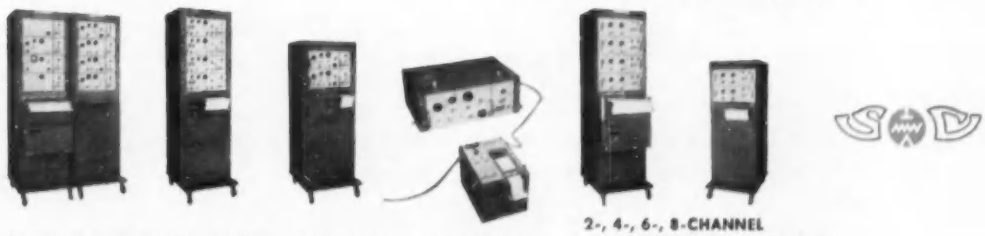
**Sanborn's galvanometer writing arms record valuable data to help solve the countless measurement problems of research, design, and production testing.**

SINGLE to 8-channel inkless and permanent recording in true rectangular coordinates of 0-100 cps phenomena — ranging from telemetered aircraft data to atomic reactor characteristics — is the vital and growing role of Sanborn oscillographic recording systems in industry. The Sanborn file of users indicates that such recordings are aiding in the dynamic analysis of jet engine starters, machine tools, agricultural machinery and oil drilling equipment; performance of pilotless target aircraft, modern submarines and tracking radar systems; and the production testing of servo components, valve positioners and precision potentiometers. Sanborn systems designed especially for recording analog computer output extend applications further — in simulated flight set-ups, solution of complex problems with six or eight variables, etc.

The advantages of making Sanborn equipment the "right arm" of *your* recording problems include extreme *flexibility*, by means of a dozen different interchangeable, plug-in "150 Series" preamplifiers which quickly and economically adapt a basic system to changing requirements; choice of 1-, 2-, 4-, 6- or 8-channel systems, in vertical mobile cabinets or "portably packaged"; numerous chart speeds, many individual channel controls, and high over-all system linearity.

To see how oscillographic recording the Sanborn way can become the "Right Arm" of *your* analysis work, write for detailed information or contact your Sanborn Representative. Sixteen-page "150 System" catalog on request.

**SANBORN COMPANY**
*Industrial Division, Cambridge 39, Mass.*



8-, 6- CHANNEL | 4-CHANNEL | 2-CHANNEL | 1-CHANNEL | 2-, 4-, 6-, 8-CHANNEL ANALOG COMPUTER SYSTEMS

## WHAT'S NEW

research and engineering, joined Burroughs in 1949 as director of research activities at Paoli, Pa. Bower came to the company in 1919, and before becoming vice-president in 1946 was an experimental engineer, chief experimental engineer, and factory manager at Detroit.

▶ The new director of engineering of Bendix Aviation's Pacific Div. has worked with guided missiles since 1941, when their possibilities were just coming into focus as a result of studies in radar receivers. He is **Ralph A. Lamm,** formerly head of special missile development of Bendix's Research Laboratories Div. In 1941 Lamm was associated with MIT's Radiation Lab, which then was doing radar work. His assignments there led to an appointment as head of the MIT Field Experimental Station, which did research in, and developed and designed, complete missile guidance systems and their components. Later he was named consultant to the Bureau of Ordnance of the Navy, and in 1948 became chief of the Missiles Div. of the National Bureau of Standards. In 1951 NBS appointed him assistant director and chief of the Missile Div. of its then-new Corona Labs, and when the Corona unit became part of the Navy Bureau in 1953, Lamm was made technical director.

▶ The general engineering divisions of two companies—Valvair Corp. and Sinclair-Collins Valve Co.—are under new Chief Engineer **Richard R. Kesti,** a missile valve and control specialist. Kesti's former affiliations include Chrysler Corp. and Redstone Arsenal, Huntsville, Ala.

▶ **Charles D. W. Thornton,** who has been appointed director of research of Farnsworth Electronics Co., has an interesting background in atomic energy and nuclear physics. His work in these fields started in 1939, when he joined Eastman Kodak Co. as a research chemist, and continued at Tennessee Eastman Corp., where he participated in the pioneer experiments at Oak Ridge. Before joining Farnsworth Thornton was director of the general manager's office of operations and planning of the AEC.

▶ Vickers, Inc., has appointed **Gerhard Reethof,** formerly an assistant professor of mechanical engineering at MIT, chief of research under **Duncan Gardiner,** director of research and development. At the same time **LeRoy D. Taylor,** who has been with Vickers since 1948, becomes assistant chief engineer for development. Reethof, who was a Fulbright lecturer on machine design 1953-54, also was with

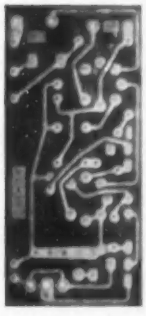

## SONIC INDUSTRIES' PHONOGRAPHS AND COMBINATIONS USE GENERAL ELECTRIC "THRU-CON" PLATED PRINT WIRE BOARDS

The chassis requirements of Sonic Industries' famous "Capri" models could not be met with conventional etched type circuits or wiring. Sonic engineers utilized the space-saving, two-sided characteristic of General Electric exclusive "Thru-Con" process to design their compact chassis.

Plated-through holes made the use of eyelets unnecessary and permitted high-speed, low-reject dip soldering.

Now General Electric "Thru-Con" print wire boards are used on *all* Sonic Industries' models.

Manufacturers of all products where wiring is required should investigate the space-saving, cost-saving features of "Thru-Con" print wire boards.



COMPACT CHASSIS BOARD USED IN SONIC INDUSTRIES' TWIN SPEAKER PORTABLE HI-FI PHONOGRAPH. SPACE AND WEIGHT PROBLEM REDUCED TO A MINIMUM WITH "THRU-CON".

*for descriptive brochure write:*

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## WHAT'S NEW

Sperry Gyroscope and General Electric.

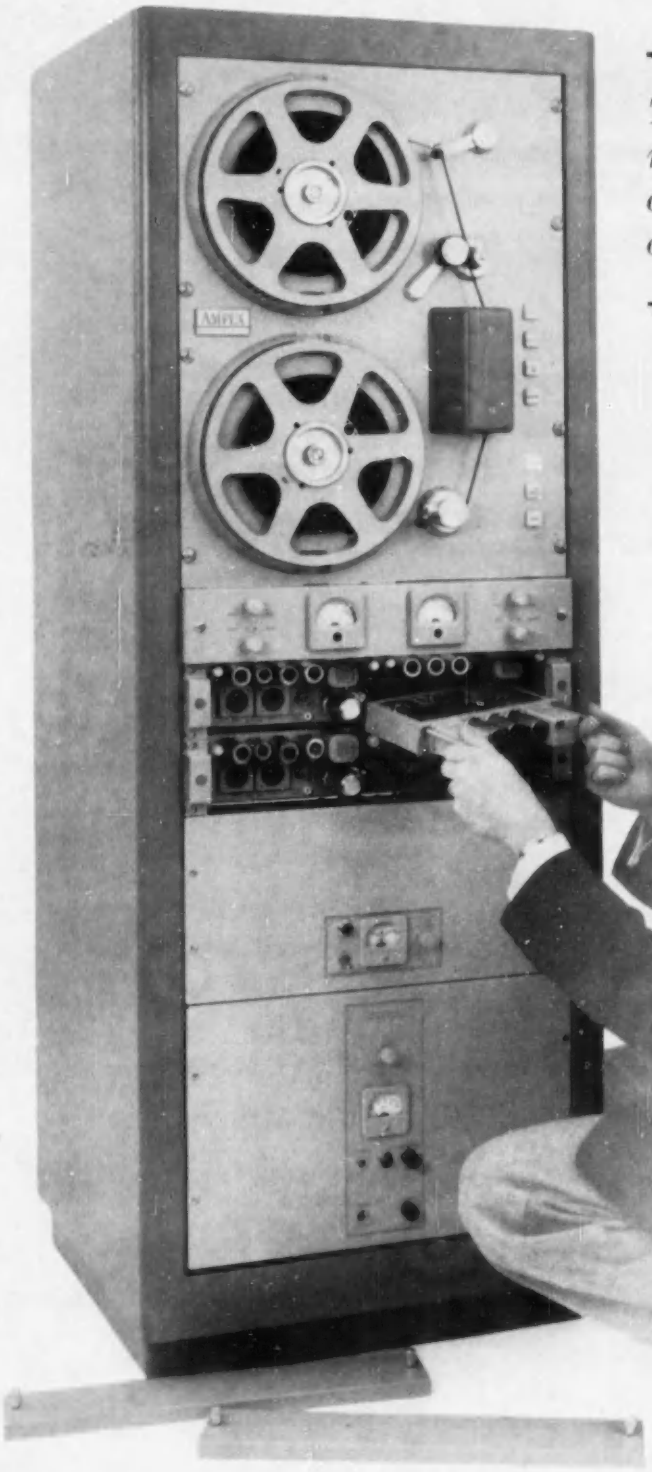
▶ Directing the application of data processing equipment and mathematical techniques to steel operations at Kaiser Steel Corp. will be **Michael Montalbano**, the new director of computer research. Montalbano joined Kaiser in 1954 as a mathematician, after experience with the National Bureau of Standards and the Naval Research Laboratory.

▶ **G. Lupton Broomell Jr.** succeeds **John W. Harsch** as director of engineering of Leeds & Northrup Co. Harsch came to L&N in 1923 from Inland Steel Co. and the Mellon Institute, and in 1926 received the first of a series of patents in forced convection heating, atmosphere control, and related subjects. Among his honors for work in this field are the Trinks Industrial Heating Award and the Naval Ordnance Development Award. Broomell has been assistant director of engineering.

▶ **Raul H. Frye,** appointed general manager of Fairchild Camera & Instrument Co.'s Electronics Div., comes from American Machine & Foundry Co., where he held the identical post. He has also been with National Co., Inc. (vice-president for engineering), Raytheon Mfg. Co. (general manager of the Special Products Div.), and American Television & Radio Co., Electronic Laboratories, Inc., and the Navy Dept.

▶ Stanford Research Institute has formed a Mathematics Group to service the various research programs at Menlo Park, and has made a key appointment in its Computer Laboratory. The new group is headed by **Clay Perry,** who is assisted by **George Evans.** Other staff members: **Clarence M. Ablow,** senior research mathematician; **Carson Flammer,** senior mathematical physicist; **Ralph E. Keirstead,** research mathematician and chief programmer; **Walter E. Weibenson Jr.,** research mathematician; **Marilyn Anderson, Elizabeth A. Clarke, Mary M. Humphrey,** and **Jean H. Waters,** mathematicians; and **Curtis Perry** and **Leonard Leving,** mathematical assistants. New member of the Computer Laboratory is **Torben H. Meisling,** whose title is senior research engineer. Meisling, a specialist in systems design, has been connected with MIT's Lincoln Laboratory and the University of California. He taught digital computer design at the university and lectured and did research on computer projects there.

*(Other important moves, page 191)*



# THE NEW AMPEX FR-1100

*The best things magnetic tape recording can do combined in a single instrument of moderate cost*

## THIS RECORDER IS YOUR BEST CHOICE

- **IF** you are equipping a laboratory and want facility for everything that comes along.
- **IF** you are an expert improving your methods before a bigger equipment purchase.
- **IF** you are starting from scratch to evaluate magnetic tape as a data or control technique.
- **IF** you have a specific need for an instrumentation recorder with a maximum of two tracks.

Features of the FR-1100 include interchangeable plug-in amplifiers, interchangeable heads and four tape speeds. It can equal (and surpass) five standard two-track recorders in Ampex's familiar 300 Series (303, 306, 307, 309 and 311 – also a 303/306 combination). Photograph shows a two-track FR-1100 equipped with a meter panel and Servo Speed Control. Both tracks are available for data, even when the Servo Speed Control signal is recorded on one of them.

In addition to its versatility, the FR-1100 has basic improvements in performance over the previous models it supplants. Specifications and a complete description should be in your information files. Write today to Dept. HH-296

**District Offices:** *Atlanta; Chicago; Dallas; Dayton; Los Angeles; Montclair, New Jersey (New York Area); Palo Alto, California; Silver Spring, Maryland (Washington D.C. Area); Toronto, Ontario (Ampex-American).*

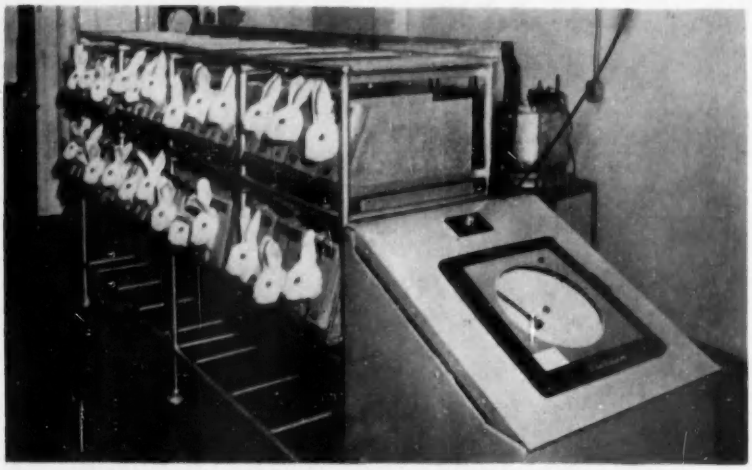
INSTRUMENTATION DIVISION

AMPEX CORPORATION

FIRST IN MAGNETIC TAPE INSTRUMENTATION

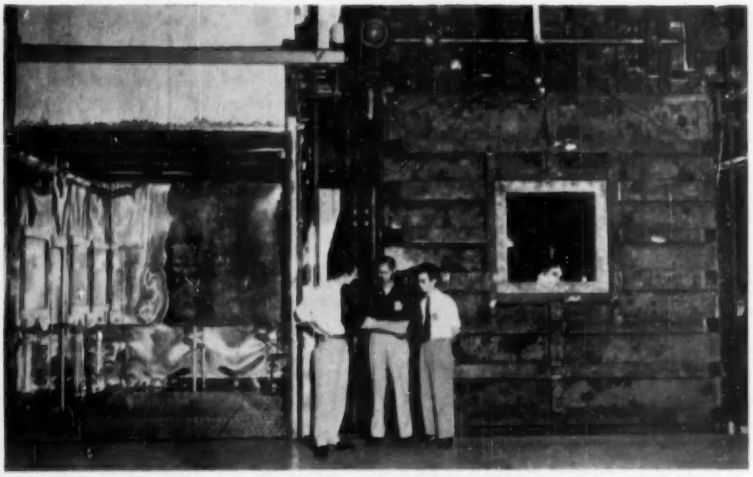
934 Charter Street • Redwood City, California

## WHAT'S NEW



### Even Rabbits Like Fielden's Automatic Test for Pyrogens

This may look like a picture of the rabbit section in the ball-park bleachers (full of rabid fans, naturally), but it happens to be something quite different: a stage in a standard pyrogen test procedure designed and engineered by the Fielden Instrument Div. of Robertshaw-Fulton Controls Co. The technique for testing for pyrogens (a fever-creating substance that is itself free of living bacteria) is a medical rather than an engineering matter; however, of interest to the control man is the fact that before the development of the automatic temperature indicating and recording system, the entire pyrogen test was carried out manually.



### Scientists Simulate Rough Environment for Instruments

Westinghouse Electric Corp. engineers running tests on airborne electronic systems are sending them 80,000 ft into the air, heating them to 500 deg F, and cooling them to minus 100 deg F, all while the systems are standing still. The secret is a pair of brand new environmental testing chambers at the company's Air Arm Div. at Baltimore. Instrumentation in one chamber provides the means for simulating rain humidity and salt spray, in the other high altitudes and high and low temperatures. Reaching the 80,000-ft level takes 25 min, going to 185 deg F from room temperature takes 2 hours. Insulation of the two chambers is made of fiberglass, walls and ceilings are of stainless steel. Each one measures 10 by 8 by 16 ft. A special 2-ft-thick, four-ton door moves down in front of the altitude chamber to permit "floor-level" loading of heavy equipment.

## WHAT'S NEW

### All Around the Business Loop

▶ The country's two biggest makers of electronic data machines, which for more than a year have been grumbling about each other's practices in the calculator field, have made up. Because of the size of **IBM** and **Sperry Rand**, and because of the influence they carry in the industry, there probably could have been no more satisfactory truce than the one agreed on in New York last August. Under its terms, a nonlicensing agreement has been set up to exchange licenses to manufacture punched-card accounting machines and electronic data calculators under respective patents and patent applications in existence as of last Oct. 1.

Recognizing IBM's predominence in production, the pact calls for this company to pay Sperry $1,250,000 a year for the next eight years, this money to be credited against production royalties. After this time, the payments will cease.

The actual claims and counterclaims filed by the companies against each other (Sperry's, an anti-trust complaint, was filed last December, while IBM's counter, charging patent infringement, came in June) are automatically disposed of by a procedure for settling patent interferences and for exchanging technical information about all machines announced or released to production before Oct. 1.

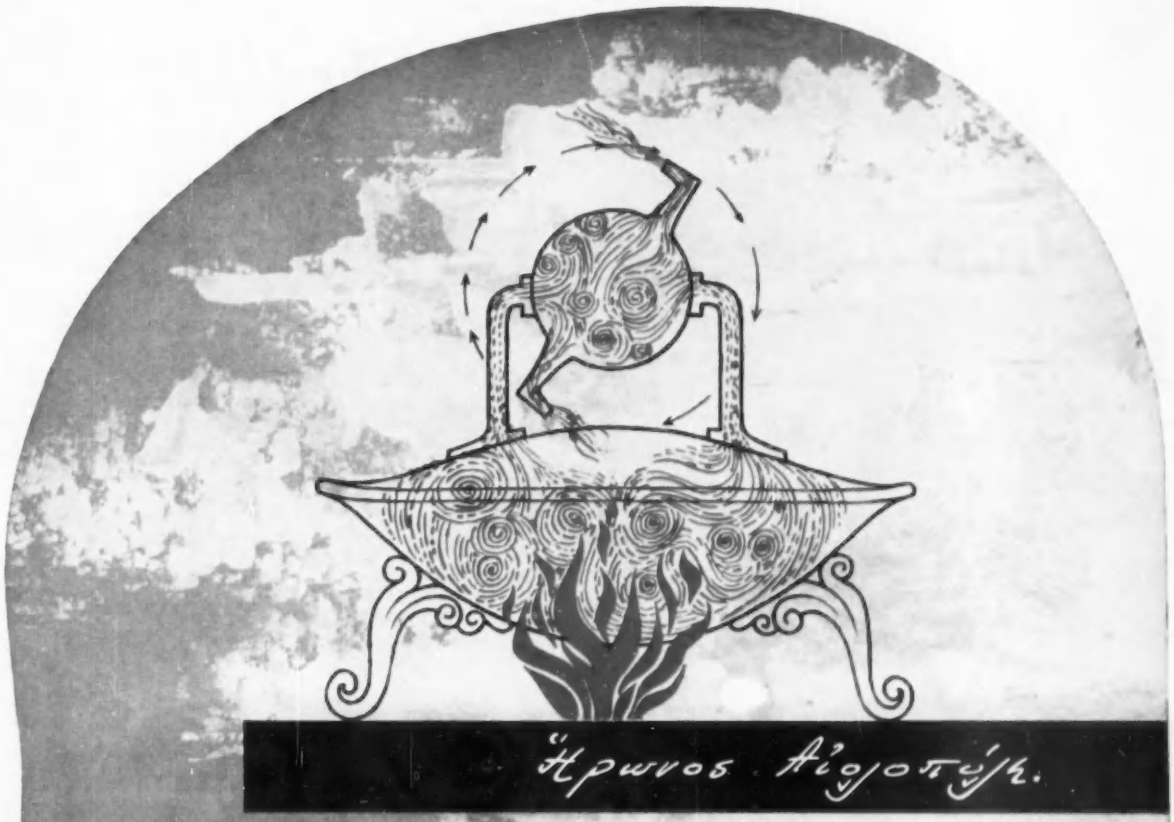
▶ The Loctite sealant for metals, described in the *New Product* section last month (page 153), is the principal reason for the existence of a fairly new company in Hartford, Conn., known as **American Sealants.** Vernon K. Krieble, who developed the chemical compound, founded the company to manufacture and market it shortly after his retirement from Trinity College, where he was Scovill Emeritus Professor of Chemistry. Originally intended as a pasttime, the company grew so fast that Krieble had to call in son Robert, a PhD in chemistry who was manager of the **Chemical Development Dept.** of **General Electric,** as vice-president, and a couple of other men to help him with advertising, sales, and promotion. One of American Sealants' latest orders: a six-figure security issue, which the elder Krieble sold almost singlehandedly.

▶ **Panellit's** new subsidiary, **Panellit Service Corp.,** will take over the parent company's **Instrument Services Div.** and expand activities in instrumentation and automation. Neil M. Blair, who managed ISD, has been named vice-president and general manager of the new corporation.

### TWO MOVES IN CALIFORNIA

Lear adds a building in Santa Monica: Grand Rapids Div. gets a West Coast branch


Expansion by Perkin Engineering: a clean slate for work in sheet metal fabrication.




## Heron's Aeolipile

In the 3rd Century B.C., 2,000 years before Newton, Heron of Alexandria anticipated modern concepts of jet propulsion with his working model of the aeolipile, a steam-driven forerunner of today's rocket engines.

Heron, Newton, Goddard, von Kármán...the principle endures, the need evolves, the powerplant is born. In our time, Aerojet-General Corporation represents the culmination of research, development and manufacturing in rocket propulsion.

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Engineers, scientists...at Aerojet-General your opportunity for creative expression is bounded only by the limits of your imagination.

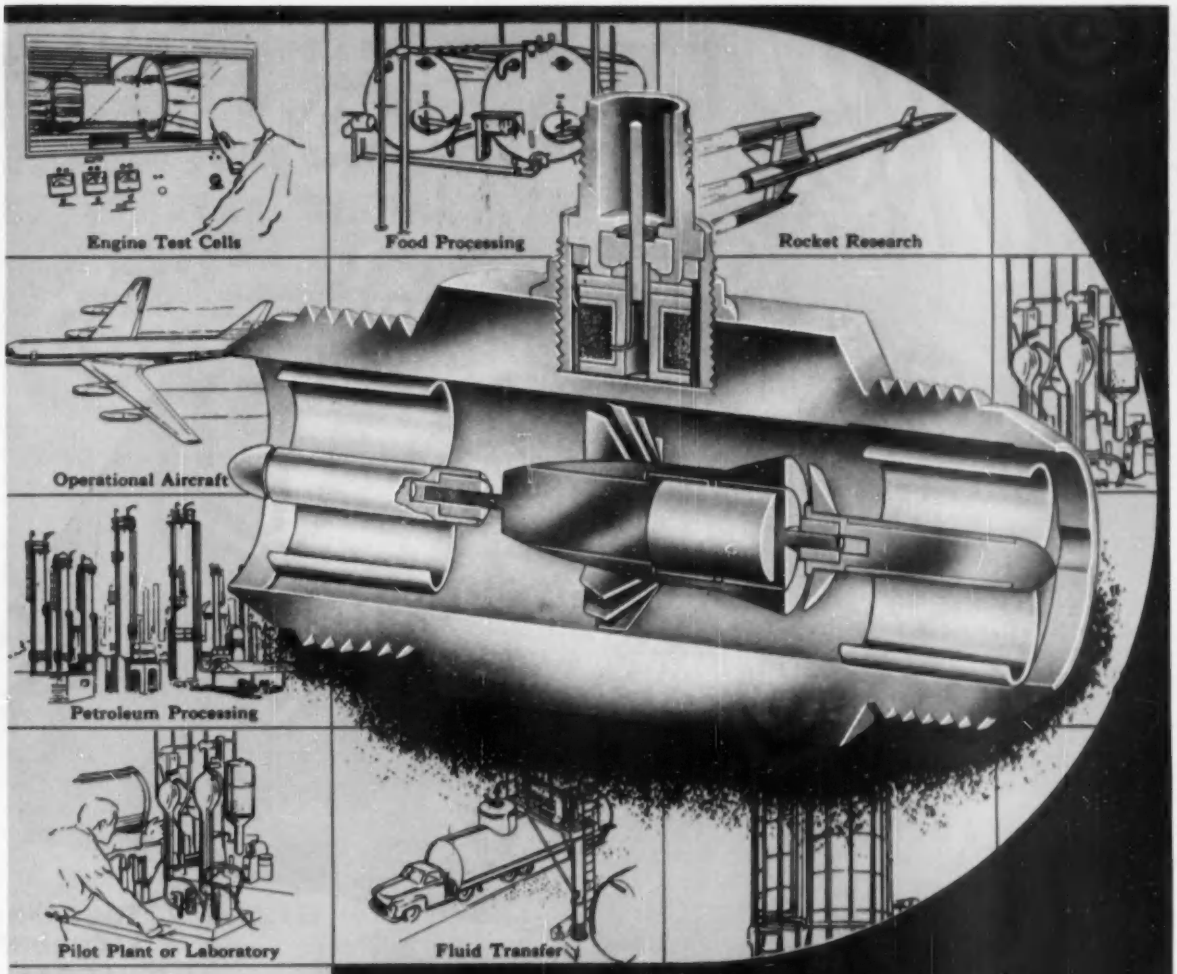
## WHAT'S NEW

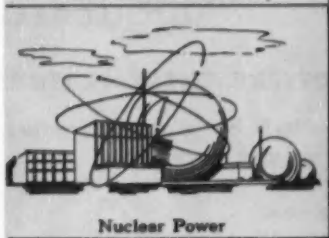
► New **IBM** data processing centers in Zurich, Switzerland, and Stockholm, Sweden, bring to five the number of such centers in Europe. Others are located in Stuttgart, Germany, London, and Paris. The company also has similar centers in Rio de Janeiro, Caracas, and Toronto. All are designed to handle scientific, engineering, accounting, and statistical computations, and data processing. IBM is making use of its diversified manufacturing facilities to supply the two new centers: the 650 magnetic drum processing machine planned for Zurich is being produced in Germany, while the one earmarked for Stockholm will come out of the company's plant in France.

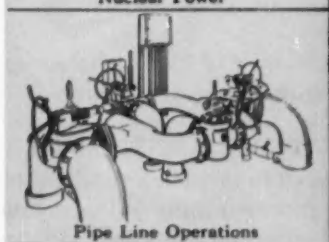
► Scientists and engineers studying the possibilities of machine translation of languages have taken another gigantic step. Now that word-for-word translation is looming over the technological horizon, they have started thinking about sentence-for-sentence translation. The work, most of which is being done at **MIT's Research Laboratory of Electronics**, was described to the AIEE by Victor H. Yngve at the recent Fall General Meeting in Chicago. "The translations produced by a routine that translates on a sentence-for-sentence basis will be vastly better than the output of a word-for-word translation machine," he said. "Most output sentences will be grammatically correct. There will be very few word-order problems remaining. Many of the multiple-meaning difficulties will be solved, particularly those involving the most frequent words of the language and the very frequent inflectional endings." Yngve added this bit to the Needless-to-Say Dept.: providing translation routines on a sentence-for-sentence or structural basis requires a lot of detailed linguistic work.

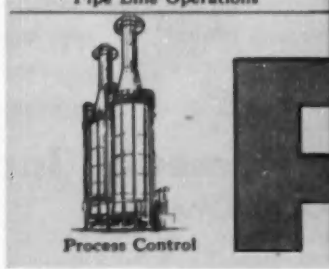
► **The National Science Foundation's** first grant to colleges and universities in support of computation centers and research in numerical analysis totals $135,000. Recipients are **Cal Tech**, $38,000; **MIT**, $30,000; **Oregon State College**, $20,000; **University of Washington**, $17,500; and **University of Wisconsin**, $30,000. The funds will be used to establish new computing centers, expand existing ones, pay rental for computing time, and in some cases pay salaries of research assistants. The foundation noted in making its announcement that numerical research in this country is not as extensive as it could be. Among reasons given: the few large computing centers now operating are available

(More business news, page 186)

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In every industry where liquid flow information is required, Pottermeters have set new standards of accuracy and reliability.

The only "bearingless" flow meter, the Pottermeter is unaffected by caustics, acids, corrosives and completely reliable even under extreme conditions of temperature and pressure.

Potter engineering has solved many "impossible" flow control problems. Maybe we can help you.

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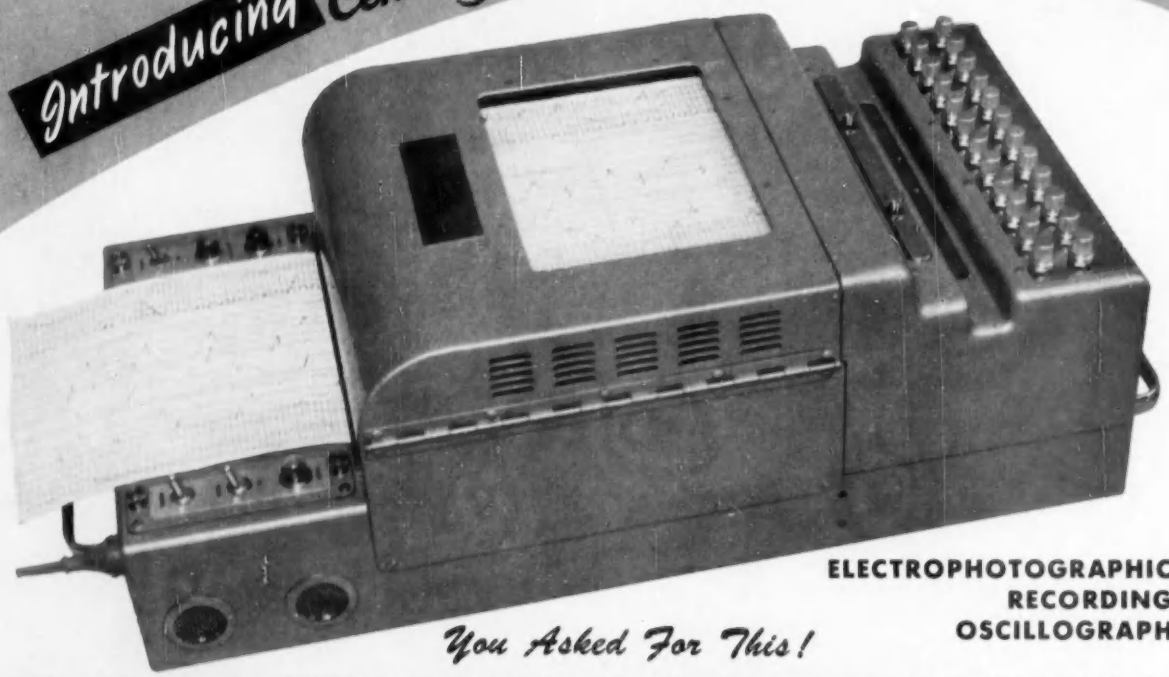
# NOW! FOR THE FIRST TIME

## DIRECT WRITING CONVENIENCE WITH PHOTOGRAPHIC ADVANTAGES!

*Introducing* **Century ELECTROGRAPH MODEL 420**



**ELECTROPHOTOGRAPHIC RECORDING OSCILLOGRAPH**

*You Asked For This!*

### ONLY THE REVOLUTIONARY CENTURY ELECTROGRAPH OFFERS THESE FEATURES

- ***Permanent instantaneous oscillograms***
- ***Eliminates need for messy liquid chemicals***
- ***No darkroom required***
- ***Automatic continuous dry processing***
- ***View oscillogram while recording***
- ***Utilizes sensitive light-beam galvanometers***
- ***Up to 24 traces on eight inch paper***
- ***Traces can overlap***
- ***Precision timing lines***
- ***Low power consumption***

Century's engineers are the first to accomplish the long dreamed-for wedding of photographic recording and completely automatic dry processing to eliminate the need for costly darkroom facilities and liquid developing, rinsing and fixing.

The greatest advancement in the technique of multi-channel oscillograph recording in over 20 years, the CENTURY ELECTROGRAPH is essentially a direct-writing recording oscillograph utilizing the RADICALLY new technique of Electrophotography combined with light-beam galvanometers.

NOW investigate CENTURY ELECTROGRAPH—the most modern approach to simplified oscillographic recording — when planning your instrumentation program whether for research, engineering, test, quality control, process control, or any other analog recording requirement.

***COSTS NO MORE THAN OLD-FASHIONED METHODS***

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# NOW-PORTABLE
# 400 cycle power

This new frequency changer makes it possible to provide well regulated 400 cycle power conveniently and quickly. This unit, Model FCR 250, is extremely useful in a wide variety of applications including testing, production, airborne frequency control, computers, missile guidance system testing, and in practically any application where the use of 400 cycle power is advantageous.

Model FCR 250 is only one of a complete line of frequency changers available from Sorensen . . . the authority on controlled power for research and industry. Write for complete information.

ELECTRICAL CHARACTERISTICS

| | |
|---|---|
| Input | 105-125 VAC, 1 phase, 50-65 cycles |
| Output voltage | 115 VAC, adjustable 105-125V |
| Output Frequency | 320-1000 cps in two ranges |
| Voltage regulation | ±1% |
| Frequency regulation | ±1% (±0.01% with auxiliary frequency standard fixed at 400 cycles) |
| Load range | 0-250 VA |

MODEL FCR 250

SORENSEN & COMPANY, INC. Sorensen STAMFORD • CONN.

*In Europe, contact Sorensen-Ardag, Eichstrasse 29, Zurich, Switzerland, for all products including 50 cycle, 220 volt equipment.*

# NEW CONTROLLER LINE ADAPTS 576 WAYS

## Fenwal Announces Low-Cost Temperature Indicating Controllers

ASHLAND, MASS. — Fenwal Inc., has announced here that tailor-made, accurate, low-cost temperature indicating controllers are now available from stock.

Tailor-mades from stock are made possible by the development of the new Fenwal Series 541 line. The Series 541 is a standardized line of matched temperature indicating controller parts which can be combined easily in 576 ways.

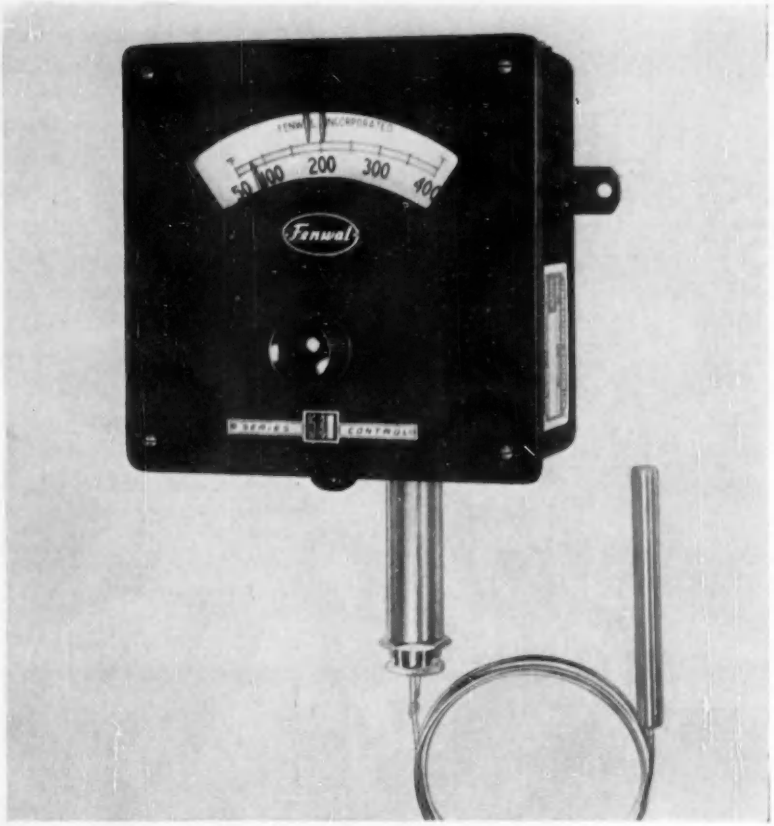
From these possible combinations come perfect solutions to countless temperature control problems. A prospective user lists the characteristics of the ideal temperature indicating controller for his particular operation, and Fenwal assembles an instrument with those characteristics from parts in stock.

No matter what combination is chosen, the result is a rugged, accurate, compact and easily maintained unit in a shock-proof, splash-proof, dust-proof housing. The housing is available in colors to match any equipment in which it may be installed.

Installation and calibration are so simple that instrument technicians and laboratory procedures are unnecessary. And, after installation, all normal temperature adjustments are external.

No matter what combination is chosen, the resulting instrument is accurate to within one per cent of scale. The accuracy is long lasting, with few moving parts and no internal gears. Simplicity of design brings the wear factor close to zero.

Series 541 offers single or double circuit control. There is a choice of four different long-life snap switches, with ratings up to 20 amps, 250 volts, A.C. These switches, singly or in combination, can provide a wide variety of operating characteristics.




One of Fenwal's new Series 541, bulb-and-capillary controllers. Photo shows dual circuit model which has two snap switches, each with a setpoint indicator, that actuate two separate circuits at the pre-set temperatures.

Three stainless steel bulb types are available at no increase in price to meet space or process requirements. Capillaries and bulbs are corrosion-proof. Capillaries are swivel-mounted to protect them from breakage.

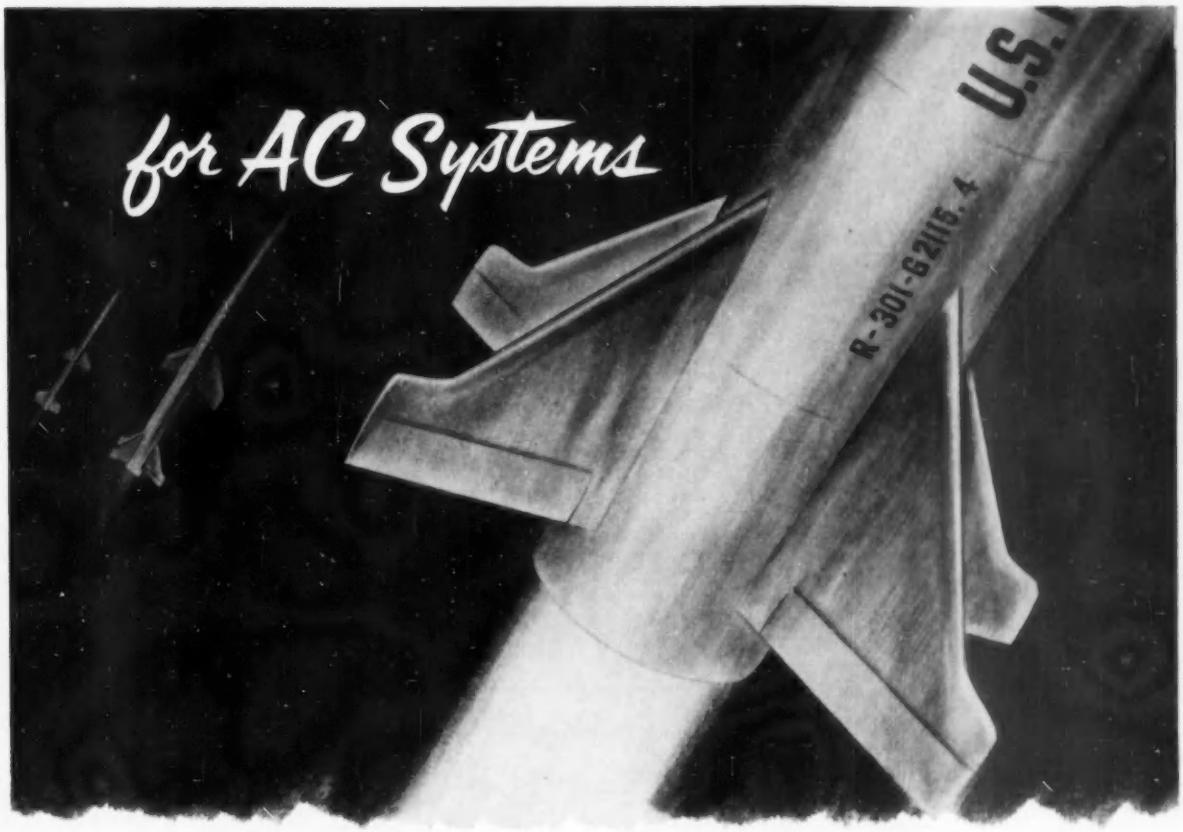
There is a choice of three temperature ranges: −150° to 200°F, 50° to 400°F, or 50° to 700°F, or their centigrade equivalents. Special ranges are available on request.

The control mechanism may be subjected to temperatures up to 150°F, and is ambient compensated from 50° to 150°F.

Write to Fenwal Incorporated, 5911 Pleasant Street, Ashland, Mass. Describe the tailor-made temperature indicating controller that would fit your operation perfectly. Chances are excellent that the tailor-made can be yours — at savings never before possible.

**Fenwal**

**CONTROLS TEMPERATURE ... *PRECISELY***




## cppc SIZE 8 SYNCHROS FOR

# ACCURACY • RELIABILITY • LESS BULK • LESS WEIGHT

In our new size 8 series of synchros shown below, we are guaranteeing accuracies of 7 minutes or less from EZ.

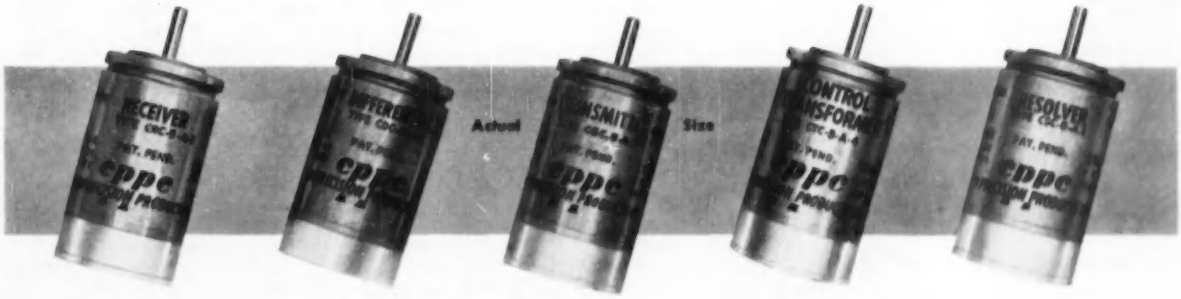
In no other synchros is such accuracy packed in so light and small a package. Length from face is 1.240" and weight 32 grams.

Write or telephone us your requirements (MAdison 6-2101, Suburban Philadelphia).

*Look to CPPC for Synchros Progress*

**CLIFTON PRECISION PRODUCTS CO., INC.** Clifton Heights, Pa.

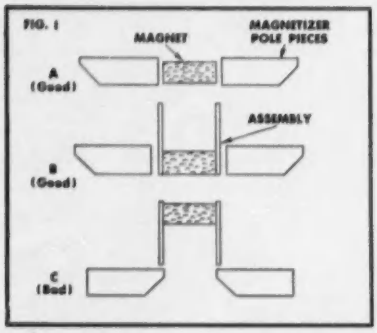
| STANDARD UNITS | | ROTOR | | | | | | STATOR | | | | | | IMPEDANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SYNCHRO FUNCTION | CPPC TYPE | Input V400cy | Input Amps | Input Watts | Ohms (DC) | Output Rotor | Sensitivity (MV/deg.) | Output Volts | Sensitivity (MV/deg.) | Input Volts | Input Amps | Input Watts | Ohms (DC) | Zro | Zso | Zrss | Phase R-S | Shift S-R | Nulls (MV) | Possible Error | Possible Spd. | Length in inches |
| Torque Transmitter | CGC-8-A-7 | 26.0 | .100 | .5 | 37 | — | — | 11.8 | 200 | — | — | — | 12 | 54+j260 | 12+j45 | 76.4+j19.6 | 8° | — | 30 | 7′ | 14′ | 1.240 |
| Control Transformer | CTC-8-A-1 | 26.0 | .050 | .25 | 143 | 24 | 410 | 11.8 | 200 | 11.8 | .090 | .23 | 25 | 220+j740 | 28+j110 | 246+j60 | | 8.5° | 30 | 7′ | 14′ | 1.240 |
| Control Transformer | CTC-8-A-4 | — | — | — | 381 | 24 | 410 | — | — | 11.8 | .037 | .09 | 60 | 508+j1680 | 67+j270 | 640+j190 | — | 9.2° | 30 | 7′ | 14′ | 1.240 |
| Control Differential | CDC-8-A-1 | — | — | — | 36 | 11.8 | 200 | — | — | 11.8 | .085 | .21 | 25 | 38+j122 | 27+j120 | 48.6+j13.8 | — | 9° | 30 | 7′ | 14′ | 1.240 |
| Electrical Resolver | CSC-8-A-1 | 26.0 | .039 | .43 | 230 | 23.2 | 400 | 10.6 | 180 | 11.8 | .084 | .27 | 27 | 280+j600 | 38+j136 | 70+j136 | 20° | 11° | 30 | 7′ | 14′ | 1.240 |
| Torque Receiver | CRC-8-A-1 | 26.0 | .100 | .50 | 37 | — | — | 11.8 | 200 | — | — | — | 12 | 54+j260 | 12+j45 | 85.1+j20.4 | 8° | — | 30 | 30′ | 30′ | 1.240 |



INDIANA
PERMANENT MAGNET
DESIGN INFORMATION

published for industrial and consumer product engineers and designers

## HOW TO MAGNETIZE PERMANENT MAGNETS




Magnetizing permanent magnets after assembly into the product offers several advantages. Higher field strengths are obtainable. The magnetic field produced in a loudspeaker, for example, using an Alnico V permanent magnet that has been magnetized after assembly, is about three times as great as the field obtained when the same magnet is magnetized before assembly.

The unmagnetized magnets are easier to handle and to assemble with other parts of the assembly. There is less contamination due to pick-up of magnetic particles.

Magnetizing after assembly is also advantageous in such applications as watt hour meters, polarized relays, and permanent magnet motors.

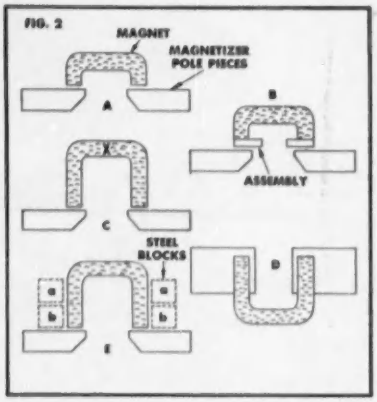
### Using the Magnetizer

Most commonly used magnets are of simple bar or "U" shapes, which may be magnetized with an electromagnetic magnetizer in the user's plant.

Fig. 1-A shows how a bar magnet should be positioned between the magnetizer's pole pieces. The square ends of the pole pieces are used toward the gap. The space between the pole pieces is adjusted so the magnet can be easily inserted and removed. Normally, only one to two seconds are required to fully magnetize the magnet.

An assembly consisting of a bar-type magnet and soft-steel pole pieces should be placed with the magnet between the magnetizer pole pieces as shown in Fig. 1-B. Positioning the assembly as shown in Fig. 1-C will not fully saturate the magnet.

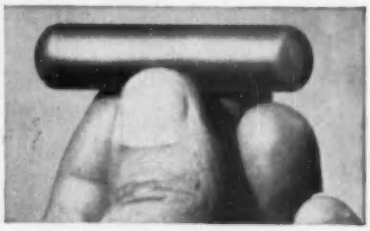
"U" shaped magnets and assemblies should be positioned as shown in Fig. 2, with the tapered ends of the magnetizer pole pieces used toward the gap. A meter or separator assembly would be placed on the magnetizer as shown in Fig. 2-B.




When a "U" shaped magnet is tall or larger than the generally accepted setting of the magnetizer, the field produced at point "X" (see Fig. 2-C) may not be sufficient to saturate the magnet. In this case there are two acceptable methods of magnetization. One is to place the magnet with its side on the pole pieces as shown in Fig. 2-D. This allows the yoke of the magnet to become magnetized. The magnet is then raised to the position in Fig. 2-C and again magnetized.

The other procedure is to stand the magnet on the magnetizer pole pieces with one or two steel blocks against each of its legs as shown in Fig. 2-E. The magnet (or assembly) is then magnetized three times: first, with both pairs of blocks in place; second, with blocks (a) removed; and third, with blocks (b) also removed.

For a complete discussion of how to magnetize permanent magnets by the electro-magnetic method, write for a copy of *Applied Magnetics*, Vol. 2, No. 3.



### Magnets protect Bossie from Stomach-aches

Cows often gulp down, with their food, various and sundry items including a surprising volume of nails, staples, wire and other metal objects. As a result, Bossie frequently gets a stomach-ache called "hardware disease."

The sharp edges of the stray metal often pierce her stomach wall, and can easily cause death.

To prevent the costly disorder, you simply feed the old girl an Indiana "Cattle Magnet." The magnet remains in her first stomach, gathering the stray bits of metal as they appear. This keeps them from passing to her other stomachs (she has four, you know) where they can cause damage.

### Report on Indox I Ceramic Permanent Magnets

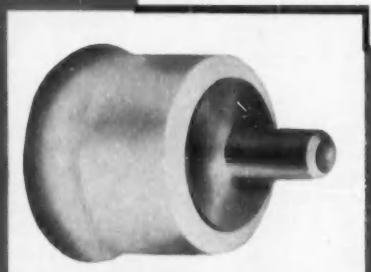
This recently published four-page technical bulletin, "Indox I Ceramic Permanent Magnets," suggests factors to be considered during design calculations, and discusses possibilities for new applications or improvements of existing ones.

Also discussed are some 30 representative sizes and shapes available in sample quantities for immediate shipment. Ask for price list and Catalog 15-P-11.

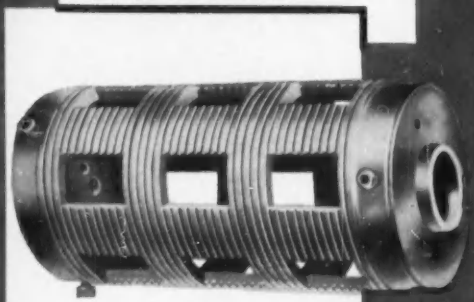
*THE INDIANA STEEL PRODUCTS COMPANY*
*Valparaiso, Indiana*
**WORLD'S LARGEST MANUFACTURER OF PERMANENT MAGNETS**

INDIANA
PERMANENT
MAGNETS

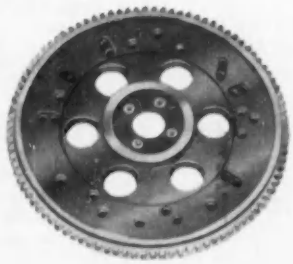
**APPLIANCE SEAL** . . . insures absolute physical seal — permanent bonding to inserts



**BRUSH HOLDER STUD** . . . maintains correct gapping under extreme conditions



**COIL FORM** . . . achieves dependable high speed, high frequency performance



**SPUR GEAR** . . . matching thermal expansion eliminates distortion and corona

# . . . . . Moldable

## SUPRAMICA® 555

# VERSATILE CERAMOPLASTIC

**. . . MAKES COMPLEX INSULATED PARTS — BETTER!**

**SUPRAMICA* 555 ceramoplastic offers an unbeatable combination of properties . . . absolute dimensional stability, high thermal endurance, every desirable electrical characteristic . . . plus precision moldability to permanent tolerances of ±.001".**

**Think how your projects can be improved by this *unique* ceramoplastic's ability to hold fragile inserts . . . expansion coefficient that matches steel . . . and distortion-free performance under widely varying conditions. Here's a single material with all the features you need . . . extremely low electrical loss . . . unexcelled arc resistance . . . complete freedom from carbonization and imperviousness to radiation effects, water, oil and organic solvents.**

**The secret of this superiority: SUPRAMICA 555 ceramoplastic's *exclusive* formulation of top grade electrical glass and SYNTHAMICA* synthetic mica. Send to Department 336 for *an Engineering Data File* on SUPRAMICA 555 ceramoplastic insulation and MYCALEX custom molding services.**

SUPRAMICA DIVISION

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WORLD'S LARGEST MANUFACTURER OF GLASS-BONDED MICA AND CERAMOPLASTIC PRODUCTS

# Simplest pneumatic controller to use and maintain

## *Bristol gives you improved stability of control action –but keeps basic simplicity of Series 500 Controllers*

Bristol Series 500 Pneumatic Controllers are the easiest controllers on the market to use and maintain–still the most dependable and trouble-free.

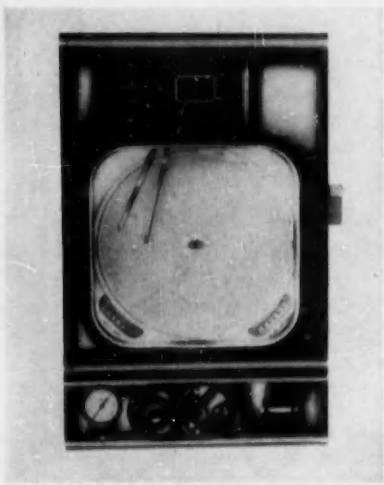
The reason? The basic simplicity of the operating mechanism. *That* hasn't changed in the years since we introduced this long-time favorite among instrument men. Reason No. 2: they are equipped with famous Bristol measuring elements.

### Easy calibration

It's this foolproof simplicity of the control system that makes calibration so easy on Series 500 controllers. *Only one* service adjustment is required and provided to exactly calibrate the control system. The control system can be completely disassembled and after reassembly (even with replacement of parts) can be restored to precise calibration with this *one* adjustment.

No special tools are required. A ¼-inch wrench is all that's needed.

The 500's completely interchangeable parts, accurately designed and manufactured to extremely close tolerances, make possible this built-in calibration.



**BRISTOL'S® SERIES 500 CONTROLLER**, shown here with four-position transfer station. Internal station also available.

### And check these features:

**Improved control stability**–advanced automatic control techniques have been applied by Bristol engineers to improve stability of control action in the new Series 500W Controllers.

**Wide-band models** offer choice of ½ to 400% proportional band with simple band shift.

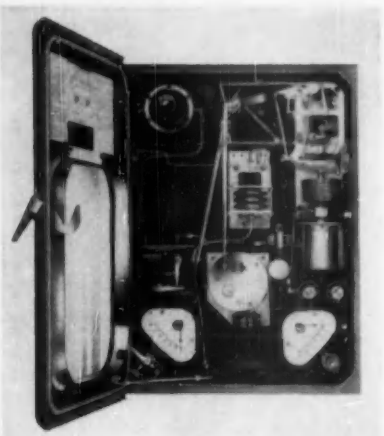
**True zero derivative setting**–exclusive with Bristol.

**Reset action stops** in reset models–again a Bristol exclusive–prevent loss of control due to prolonged deviation from set point.

**Four-position internal transfer station** with automatic, manual, test, and service positions, plus pressure-matching button and manual pressure regulator, for maximum convenience in process control.

### Complete data available

Write today for engineering data on Bristol's Series 500 controllers for your critical control problems. They're available for *automatic control of temperature, pressure, vacuum, draft, absolute pressure, liquid level, humidity, pH value, electrical measurements, and mechanical motion.* The Bristol Company, 101 Bristol Road, Waterbury 20, Conn.



**FOUR-POSITION INTERNAL TRANSFER STATION** shown here in interior view of Series 500 Controller. Permits remote manual control, testing and servicing without disconnecting instrument.

**YOU CAN GET THESE CONTROL MODES:**

1. **Fixed narrow band** (on-off)
2. **Proportional band**—½ to 100% and ½ to 30%.
3. **Reset with wide band**—rates 0.1 to 10 or 1 to 300 repeats per minute. Proportional band ½ to 400%.
4. **Derivative (rate)**—½ to 100% proportional band. Derivative time 0.2 to 20 min., plus zero derivative setting.
5. **Reset plus derivative**—proportional band and reset rate as in "reset" above. Derivative time as in "derivative" above.

**YOU CAN HANDLE THESE CONTROL PROBLEMS:**

1. Cascaded control 2. Selective control 3. Ratio control 4. Time-program control 5. Pneumatic transmission.

6.55

**BRISTOL** *TRAIL-BLAZERS IN PROCESS AUTOMATION*

**AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS**


Alumalife® Case


Phenol Case

# Why do ASHCROFT DURAGAUGE CASES increase service life?

Duragauge casings add extra-long service life to Duragauges because they're available in three different materials: you can choose the case-material that stands up best in *your application.* You have a choice of *Alumalife®* – a special aluminum alloy; *Cast Iron,* rugged and durable; and *Phenol,* a tough, rigid plastic.

Duragauge casings are dust and moistureproof. Chrome-plated, die-cast retaining rings keep the dial cover glass tightly in position and prevent the entrance of dirt or harmful fumes. Depending upon material, casings are Bonderized and the ring is Anodized and dichromate sealed for protection from corrosion.

For added protection, there is the Maxisafe Duragauge casing with a solid front – a special design for maximum safety and ease of maintenance. Duragauges are easy to service since Duragauge casings are constructed so that the entire system – socket, tube, tip, movement, dial and pointer–can easily be removed as a unit.

Lifetime Duragauge cases are available for numerous dial sizes. You have a choice of Bourdon tube materials, a wide range of pressures, and a movement made completely of stainless steel or stainless steel with nylon bearings and pinion gear.

Whatever case material and gauge system is best for your needs, you can rely on the Ashcroft Duragauge for highest sustained accuracy and long service life.

**FOR PROMPT ASSISTANCE** in selecting the right Ashcroft Duragauges for your specific needs, depend on the experience of your Industrial Supply Distributor. He is as close as your telephone.

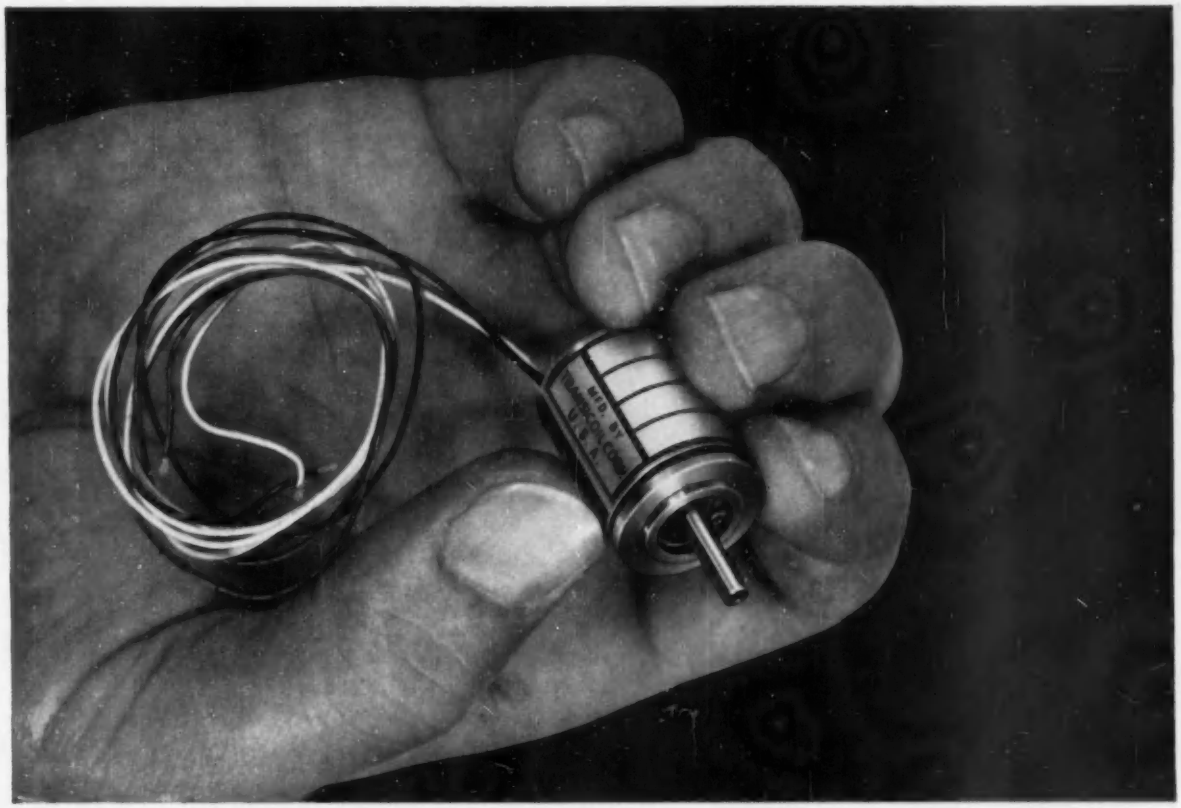
**In Canada:** *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

## ASHCROFT GAUGES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Okla.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*

G4-56



# NEW MINIATURE SERVO

## 40% Lighter, 10% Smaller

Size 8 Motor Driven Induction Generator and Transistor Amplifier. All units of the Size 8 system have been designed for maximum performance in minimum space.

Here, no bigger than your thumb, is the smallest *practical* servo control motor currently produced. Combined with Transicoil's new Size 8 motor driven induction generator, and powered by a new completely-transistorized servo amplifier, this motor offers you the unusually high torque-to-inertia ratio of 28,000 radians/sec$^2$.

Compared with a Size 9 control motor—until now, the smallest practical unit available—Transicoil's new Size 8 measures only 0.75 inches in diameter, 10% smaller, and weighs only 1.4 oz., 40% lighter. Yet it operates on standard voltages from 26 to 52 volts, and 52 volts with center tap, at 400 cps, permitting push-pull transistor application.

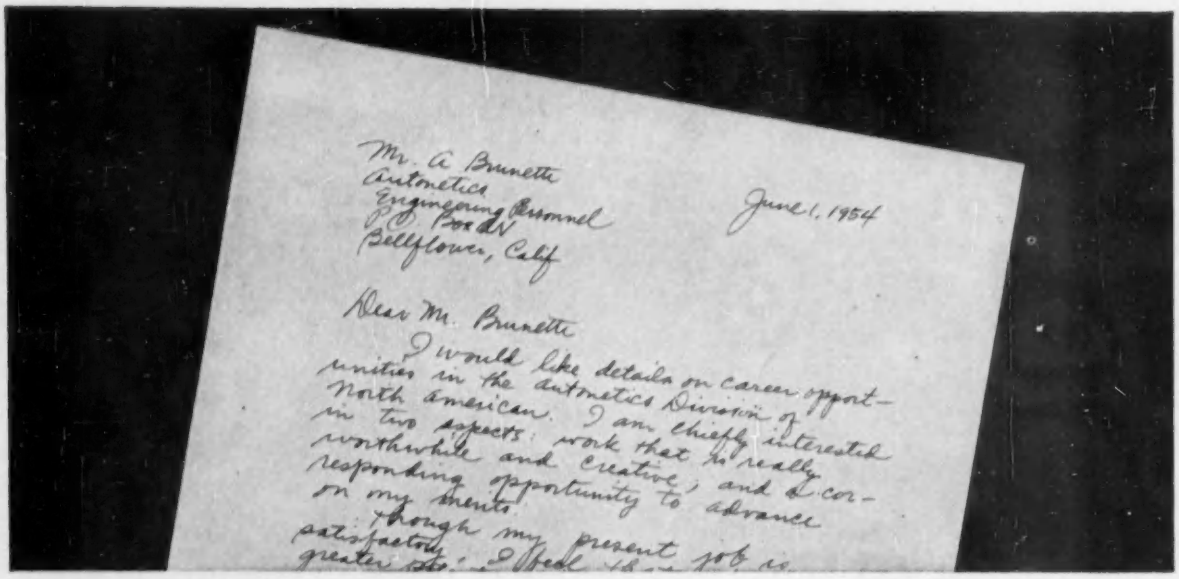
Hence, just as Transicoil's introduction of plate to plate wiring eliminated the transformer, once necessary in servo systems, the Size 8 units and transistor amplifiers mark another milestone in miniaturization.

This is just one more example of how Transicoil can solve your control problems whether they involve miniaturization or control complexity, and go on to manufacture systems and components of the utmost precision and accuracy. You pay only for results—on a fixed fee basis for equipment delivered and performing properly.

Technical data on the new Size 8 combination and the transistorized amplifier is yours for the asking. But you'll end up with a better system if you write outlining your servo control problem.

TRANSICOIL CORPORATION

Worcester, Montgomery County · Pennsylvania




# This letter moved a man ahead 5 years

Two years ago a man took 10 minutes to write this letter. Today he enjoys the responsibility and professional standing in the AUTONETICS Division of North American that might have taken 7 to 10 years to achieve in other fields.

**THE FIELD AT AUTONETICS—A FIELD OF OPPORTUNITY**

Now under way at AUTONETICS are nearly 100 projects, comprising some of the most advanced and progressive work being done today in the fields of Electronics, Electro-Mechanics, Control Engineering and Data Processing.

You will work on automatic control systems of many kinds, for manned and unmanned vehicles. Every state of the art is represented, from preliminary conception right through flight testing. Facilities are the finest obtainable. Your colleagues will be men of ability and imagination, of the highest professional standing.

The long-range potential in this field is truly limitless. The techniques being developed at AUTONETICS today will have the widest application in the industrial methods of tomorrow.

You owe it to yourself to consider how far you can advance by entering this exceptionally promising field right now. Here are the opportunities:

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Write your letter today. Decide now to get the facts, so you can make the most of your potential. Just put your address and brief qualifications on paper—handwritten will be fine. Reply will be prompt, factual, confidential.

**Write: Mr. A. Brunetti, Autonetics Engineering Personnel, Dept. 991-11 CE, P. O. Box AN, Bellflower, California**

**Autonetics**
A DIVISION OF NORTH AMERICAN AVIATION, INC.

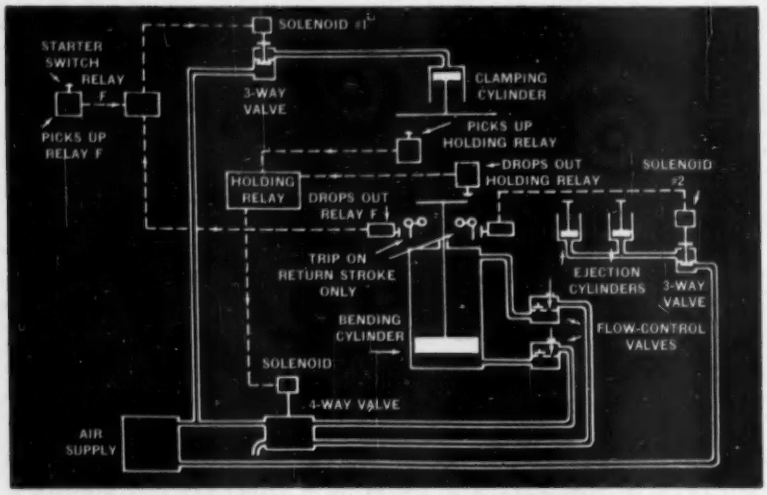
AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

*Progress Report:*

# SCHRADER AIR PRODUCTS SATISFY AUTOMATION'S NEED FOR SPEED

## Modern production quotas make speed essential

Air has always been fast acting. Its speed has made it useful in holding and releasing work fast, in blasting away scrap or waste. And today's need for speed is one of its most valuable features. In past years, the very simplicity of air often made industry lose sight of its possibilities for more complicated, essential procedures. But industrial imagination is fast catching up with itself. Hundreds of Schrader Air Products, precision-machined and extremely versatile, have opened the way to almost limitless production possibilities. The need for more units in less time through automation has found air ready, willing and able. In recent years, the natural speed of air for performing necessary functions is being utilized on a constantly increasing scale.




**Schematic shows use of Schrader Air Products for bending metal burner grills.**

***FOR EXAMPLE:***

## Burner grill production quadrupled

Bending metal rods for kerosene burner grills requires a ton of force at an oil burner corporation in Hartford, Connecticut. Before air was adapted to the job, only 150 pieces per hour could be produced. Now, with the help of Schrader Air Products, 620 pieces are produced every sixty minutes.

The accompanying schematic shows the simple arrangement of Schrader Air Products which the company developed with the help of Schrader engineers. The rapidity achieved in production, amazingly enough, is coupled with much greater safety and economy, two other features inherent in the use of air.

## Automation capabilities of Air as seen in Cylinders

Schrader Air Cylinders deliver a push, or a pull—or a pull and a push—in any direction from almost limitless positions. They will deliver a greater straight line force than that obtainable in any commonly used type of power unit of equivalent size and weight. You get strength to spare and speed to burn. Large air ports provide fast starting action for rapid cycle work. Wide interchangeability of parts gives an added premium of reduced maintenance costs.

A survey of your production machinery will reveal many instances where an air cylinder can be used to save space, time and money. Many manufacturers of original equipment are now studying the advantages of applying this low cost, universal means of supplying force to products of their own design and manufacture. They are finding that air cylinders can easily be utilized to eliminate costly mechanical movements, tiring manual labor, and space consuming mechanisms.

## Schrader engineering facilities are at your disposal

Upon request, Schrader engineers will assist in planning for the most efficient use of air in your plant, and in selecting the products best suited to a given application. Distributors are conveniently located to deliver Schrader Products in the shortest possible time. Today, these products are being turned out in mass production quantities for scores of industries. New products are also being designed constantly as acceptance of Schrader's know-how grows.

Write to Schrader for information.

Address A. Schrader's Son, Division of Scovill Manufacturing Company, Incorporated, 471 Vanderbilt Avenue, Brooklyn 38, N. Y.

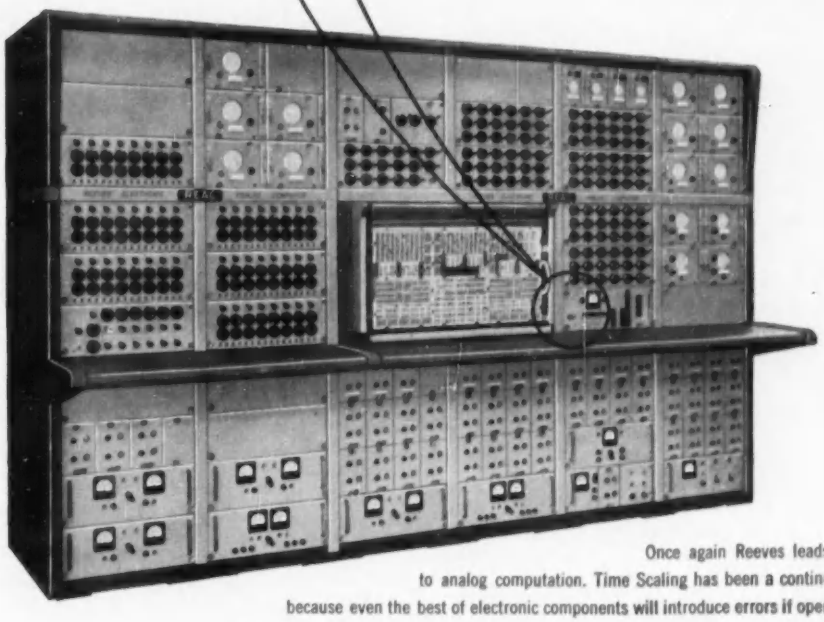
**Schrader®**
ESTABLISHED IN 1844

FIRST NAME IN THE USE OF AIR
FOR INDUSTRIAL PRODUCTION AND CONTROL

See our exhibit
BOOTH 333
3rd International
AUTOMATION
Exposition
New York, Nov. 26-30

*Another Computer FIRST*

*... by* Reeves Instrument Corporation



## BUILT-IN TIME SCALE CHECK

Once again Reeves leads the field with a major contribution to analog computation. Time Scaling has been a continued source of difficulty in analog computation because even the best of electronic components will introduce errors if operated beyond their frequency range.

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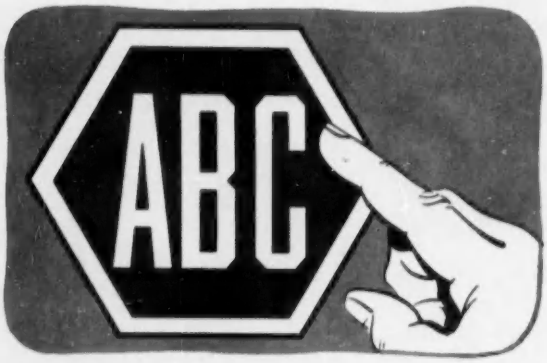


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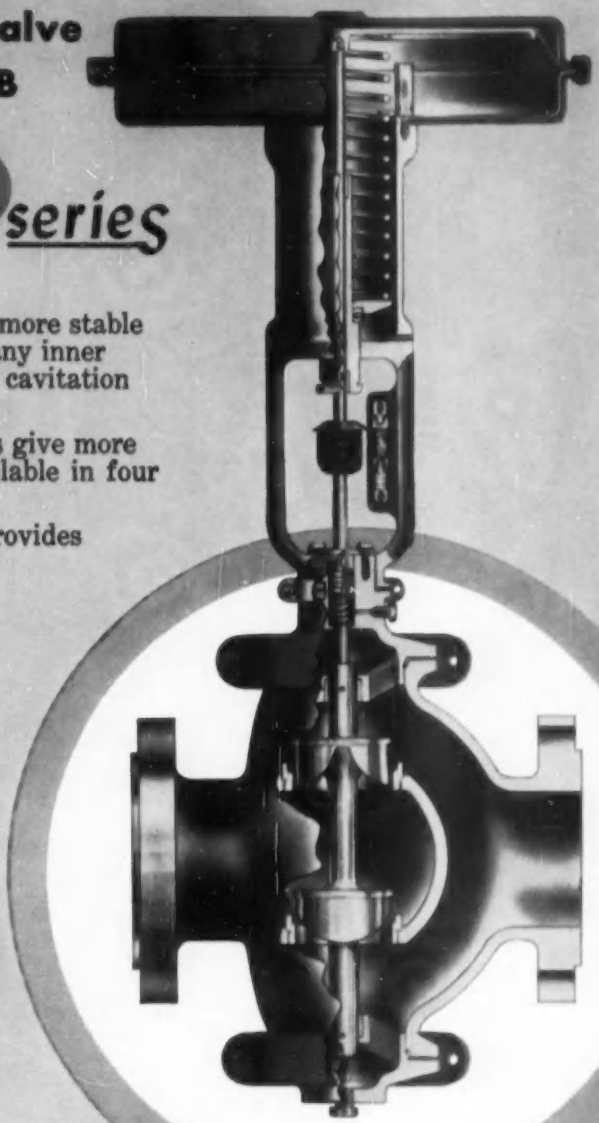

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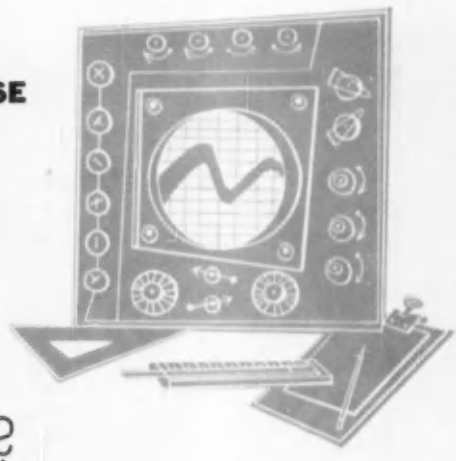

# How Do the Users View Electronic Systems?

**Pros and cons of electronics**

In the few years since vacuum-tube techniques first invaded the industrial process control field, a full-fledged controversy has emerged. On the one hand, there are many who question the work being done in an atmosphere which they call "electronic fever", while on the other there are those vacuum-tube partisans who firmly dub the opposition as "old guard".

To get a broader, calmer view of the subject, CONTROL ENGINEERING decided to tap the opinion of a large group of users. In June of this year a five-page questionnaire was mailed to 5,000 engineers selected from subscribers in the flow-process industries. To date almost 1,000 have come back. The percentage figures on answers, reviewed below, are based on 719 of these returns.

The purpose of the survey was to pin down the extent of the trend toward electronic control systems. Answers to specific questions provided valuable information about three main areas of interest:

- the kind and quantity of electronic units in use
- how these compare to pneumatic units in performance, cost, maintenance
- how users rate design features in electronic systems

**Get "off the fence"**

What can you, the user, gain from this survey? Two things. If you are "on the fence" about electronic control, the replies can guide you in making a decision. And if you are a new user of electronic techniques, you will want to see how your experience stacks up against the reports from across the field.

First let us consider how many of the people surveyed actually use or plan to use specific electronic control techniques:

| Type of Unit | Now Using | Trial Basis | Full-Scale Installation |
|---|---|---|---|
| Measuring elements | 97.1% | 11% | 93% |
| Recorders | 97.3 | 9 | 95 |
| Controllers | 91.5 | 11 | 92 |
| Electrohydraulic actuators | 53.9 | 20 | 83 |
| Electropneumatic actuators | 79.5 | 15 | 88 |
| All-electric actuators | 75.1 | 14 | 89 |

Note: Totals exceed 100% because some users have equipment on both a trial and full-scale basis.

The figures show that the bulk of engineers answering these

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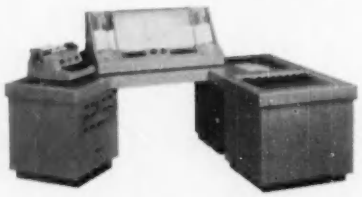

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questions already have a good deal of experience with electronic control system elements of all types. And that of the small number that answered "no" to usage, 77.4% expect to become users in the next two or three years.

**Everybody's trying it**

Next, what does the survey reveal about electronics vs. pneumatics in specific performance factors? The table below offers an interpretive answer to this question:

| Performance Factor | Better than Pneumatic | Equal to Pneumatic | Not as Good as Pneumatic |
|---|---|---|---|
| Component reliability | 16.0% | 47.9% | 36.1% |
| Stability of calibration | 32.5 | 48.8 | 18.7 |
| Measuring element (etc.) | 41.9 | 47.9 | 10.2 |
| Meas. element control pt | 39.2 | 53.1 | 7.8 |
| Speed of response (etc.) | 79.3 | 16.5 | 4.3 |
| Resolution sensitivity | 67.4 | 29.7 | 2.9 |
| "On line" maintenance | 21.6 | 31.6 | 46.9 |
| "In shop" maintenance | 19.3 | 42.2 | 38.5 |

Naturally, the opinion averages listed in the table above reflect subjective interpretations of "better", "equal", and "not as good as"—so guide your analysis of results accordingly. More concrete response was stimulated by questions on cost and maintenance. For example, 68.4% found electronic control more expensive to buy than pneumatic, 20.7% found both equal in cost, and 10.9% found pneumatic control instrumentation more costly. With respect to installation, 43.2% discovered electronic more costly than pneumatic, 29.1% found it less costly, and 27.7% could see no difference between the two. One additional thought on maintenance: 92.3% indicated that the use of electronic control had caused no change in union jurisdiction for maintenance personnel.

**How much more do you pay?**

Perhaps the most interesting data in the survey came in response to the question, "How do you rate design features in an electrical or electronic process control system?" The answers are tabled below:

| Design Feature | Essential | Important | Unimportant | Undesirable |
|---|---|---|---|---|
| All control function adjustments on front of panel | 20.7% | 53.8% | 7.6% | 17.8% |
| Miniaturized components | 10.3 | 53.9 | 31.6 | 4.2 |
| Smaller strip chart width (below 4 in.) | 1.8 | 18.8 | 31.4 | 48.0 |
| Multi-element recorders | 20.0 | 65.4 | 11.7 | 2.9 |
| Circular chart recorders | 10.5 | 37.7 | 36.8 | 14.9 |
| Valve position indicators | 28.1 | 58.4 | 13.0 | 0.5 |
| Use of plug-in assemblies | 29.8 | 62.7 | 6.7 | 0.8 |
| Deviation recorder in place of measured variable recorder | 2.2 | 33.0 | 39.6 | 25.2 |
| Use of solid-state devices (i.e., transistors, diodes, etc.) | 7.2 | 64.9 | 26.0 | 2.0 |
| Use of magnetic amplifier or ruggedized tubes | 19.6 | 68.4 | 11.2 | 0.8 |
| Split major assemblies into several packages (to ease trouble-shooting, replacement) | 32.2 | 62.0 | 4.4 | 1.5 |

Of the many interesting conclusions that undoubtedly

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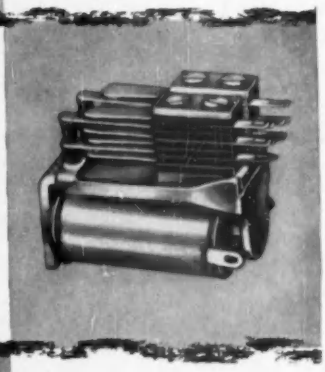

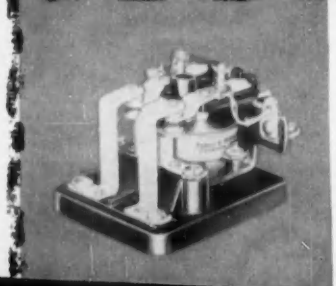

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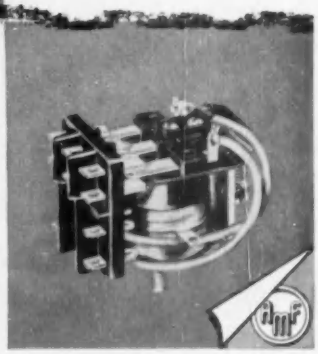
A small, low cost, highly efficient general purpose relay with 5 amp. silver contacts. Can be insulated to meet UL requirements. Size: 1 1/16" x 1 23/32" x 1 3/4". Mounting: One No. 6/32 stud and locating tab.



can be drawn from the figures in the last table, these seem to stand out as the most intriguing:

**Trends show up**

- the trend is to strip charts—and of full width
- interest in service and maintenance features is high
- interest in solid-state devices and magnetics is growing
- need for valve position information is widespread

The survey was not only concerned with the use, performance, and design aspects of electronic control; it also requested specific data on the mode of signal transmission—a factor which many hold is the strongest argument for electronics. The questionnaire asked, for example, how long signal transmission lines were. Users of pneumatic systems reported lengths up to 1,000 ft, with slightly over 50% of these users running less than 100-ft lines. Electronic signal lines, however, ran up to 5,000 ft in some cases. But the vast majority of electronic users—86.1%—were involved with lines 500 ft or less. Most respondents (68.2%) reported that use of field-mounted controllers or "boosters" had no significant effect in shortening transmission lines. Another interesting item: 68% indicated that they used both ac and dc in transmitting signals—the rest were almost equally divided between ac and dc. Peak signal voltage levels below 50 volts predominated—51.8% were in this area; 7.3% use signals above 50 volts and the remainder employ some signals above and some below a 50-volt peak level.

**Some loggings on data logging**

To assay the contribution now being made to process control by automatic data-logging equipment, several questions sought user evaluation of this special (and newsworthy) technique. CONTROL ENGINEERING plans to print the complete report on this phase of the questionnaire in a forthcoming issue. But as a preview, here is a sampling of incoming information:

- only 110 out of 685 reported they now have data logging
- 196 out of 504 are considering installations
- the most frequently mentioned use for data logging (375 replies) was "to provide information for process or plant research and analysis"

Early in the questionnaire a "sleeper" was posed—and the answers to it provide a fitting end to this *Pulse*. The question: Do you prefer electrical or electronic control systems, or pneumatic control systems, or don't you have a preference? The answers: 33.5% prefer electronic control; 31.0% prefer pneumatic control; 35.5% have no preference. We'd say that this important topic has far from lost its power to provoke controversy.

# THE SHORTAGE OF SCIENTISTS AND ENGINEERS:

# What Can Be Done About It?

**There is no easy or quick way to overcome the shortage of scientists and engineers that has become a threat to our national security and economic progress. The solution can come only through diligent efforts extending over several years to bring the supply of technically trained people into balance with our needs.** Meanwhile, the pressure of the shortage can be relieved if industry, government and education make better use of the limited number of scientists and engineers now available.

Earlier editorials in this series have discussed the dimensions of the shortage of technical manpower, its meaning for our national security and our economic well-being and the causes of the shortage. This final editorial will survey some of the measures that can be taken to overcome the shortage. Most of the proposals presented here have been suggested elsewhere. But in combination they appear to offer the best hope of an answer to this serious national problem.

## Soviet Methods Not For U. S.

**It is clear that no crash program, inspired by panic and designed indiscriminately to drive hordes of high school students into science and engineering, is suitable for the United States.** Even if we adopted Soviet methods of channeling a large portion of our brightest young people into technical fields, it would be at least four years before results appeared in the volume of college graduates. And such an approach would do no credit to the American way of life.

Any crash program, whether it involved totalitarian methods or simply overselling the advantages of technical careers, would be objectionable for other reasons as well. It would jeopardize the quality of scientific and engineering training. It would put many young people in fields where they have little aptitude and deny them to other fields for which they are better equipped. And, if carried too far, it might even result in the overcrowding that was feared prematurely a few years ago.

**The most important problems for the long run, as the preceding editorial in this series indicated, are in the area of education.** Any real solution must reduce the loss of talented high school graduates who do not continue their education for financial reasons or because of lack of interest. Also, it must improve the quality of high school preparation in science and mathematics and, above all, relieve the critical shortage of teachers.

## Basic Needs in Education

**Substantial increases in salaries of teachers in most of the nation's school systems are essential if high school students are to receive adequate preparation for courses in science and engineering.** Pay scales that have lagged behind rising living costs and salaries available in industry have placed great strain on even the most devoted teachers. There has been a sharp drop in the number of new graduates trained to teach science and mathematics, and of this smaller number many have decided not to follow careers in teaching.

Raising teachers' salaries to more realistic levels must be primarily the job of local school districts, aided by state governments. If, in face of rapid increases in school enrollments, local and state resources prove insufficient, then federal aid will have to be considered. Higher teachers' salaries, however financed, inevitably mean higher taxes. But without appreciable improvement soon, the quality of our entire educational system is in danger.

At the college level also, financial aid is needed to provide scholarships for promising students and to increase faculty salaries. (An earlier series of editorials dealt more fully with these problems, and business aid to higher educational institutions has been mounting at a gratifying rate.)

**But not all the educational problems related to the shortage of scientists and engineers can be solved with money.** Science and mathematics have steadily been de-emphasized as more youngsters have gone to high school for terminal education rather

## How business is helping to relieve the shortage of technical manpower

***Summary of a Survey by McGraw-Hill Correspondents***

Sponsoring summer study programs for high school teachers
Arranging cooperative work-and-study programs for students
Sponsoring college fellowships and scholarships in science and engineering
Paying tuition of employees taking science and engineering courses
Keeping college faculties abreast of new developments in industry
Hiring high school science teachers for summer and part-time work
Giving old, but usable, laboratory equipment to schools
Cooperating in high school science exhibits
Sponsoring regional science fairs
Sending speakers and training aids to schools
Opening plants for student tours
Analyzing jobs to relieve engineers and scientists of routine work

***The McGraw-Hill Department of Economics will be glad to hear of any other ways business is helping relieve the shortage.***

than for college preparation. This de-emphasis must be reversed.

Techniques of instruction, furthermore, can stand improvement at all levels of education. Professor E. P. Northrup of the University of Chicago observes: "In the past fifty years . . . there has been a revolutionary change in the character of mathematics, yet not a trace of this change is to be found in the curricula of all but a handful of secondary schools throughout the country." Colleges and universities may have to examine old fetishes about light teaching loads and small classes in order to make more efficient use of their faculties.

### What Industry Can Do

**Industry has the immediate problem of better utilization of available technical manpower and the long-range responsibility of helping increase our resources of trained people. Frantic recruiting practices and reckless bidding up of starting salaries—financed largely by government money for defense orders — are not the answer. There is need for earnest consideration of incentives for experienced scientists and engineers, who too often must look to sales or executive positions for adequate financial recognition.**

Industry in many instances could make more efficient use of engineers and scientists by shifting work to technicians, clerical personnel and even machines. One company found that 15% of the time of an engineering design group was spent on routine jobs and that this valuable time could be saved by adding a technician and a clerical worker to the group.

Other potential sources of technical manpower could be tapped more extensively to relieve the shortage. Very few women have entered what has been traditionally a man's world. Negroes are only slowly gaining educational and employment opportunities in technical fields. And many experienced older men can still give useful service.

### A Good Beginning

Much is being accomplished already in efforts to attract more young people into scientific and engineering careers. A summary of some of the things business is doing is presented above. Other notable contributions are being made by such organizations as the professional engineering and scientific societies (especially through their manpower commissions), the National Science Foundation, the National Research Council, the National Education Association, the National Merit Scholarship Foundation and the Thomas Alva Edison Foundation.

Results are beginning to appear in rising enrollments in engineering schools and technical institutes. Between 1951 and last year, according to McGraw-Hill's annual survey of technical institutes, enrollments in these schools rose from 46,000 to a record 67,000. Engineering enrollments rose in the same period from 166,000 to 243,000. A rising tide of graduates is already being made available to American industry.

**This is a good beginning. But only with wider appreciation of the serious implications of the shortage of scientists and engineers and intensified efforts on the part of business, government and education to relieve the shortage can we hope to overcome this threat to our national security and economic well-being.**

*This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.*

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Donald C. McGraw

PRESIDENT

**McGRAW-HILL PUBLISHING COMPANY, INC.**

Control
ENGINEERING
NOVEMBER 1956

*A Note From the Editor: The needs of the average instrument user are usually satisfied by innovations from the instrument maker. But the needs of some industries—chemical in particular—are so dynamic that they often outstrip the advance in manufacturers' product lines. The result is instrument development conducted by the "user". Fortunately, much of the know-how evolved by the user ultimately passes on to a commercial instrument maker and the development is eventually available to a broad group of industries.*

*In exploring the theme of this issue, "The Needs of Industrial Control", we were concerned with how the chemical industry actually felt about doing this instrument development work. We have invited Vic Hanson's (see page 21) answers in this guest editorial.*

# Needs Shape Markets

Why do we take on the job of instrument development? The answer lies in the nature of the chemical business. Highly competitive, it is profitable in a substantial way only for the company that gets and keeps its market by constantly developing new processes for new products and by constantly improving its methods for making existing products. When, in the mad scramble to build a plant to produce a promising new product, the need is recognized for measurements and controls beyond the capabilities of commercially available instruments, two factors favor development by the user:

- the lack of crystal-clear specifications for the instrument
- the lack of time to wait for the unit to be evolved outside

When later, another need arises, to increase production and improve product quality, two more factors appear to spur this user development:

- the limited market that a commercial version of the new device would face
- the competitive advantage to the user-developer of its exclusive installation

Once the new device is developed and at work, however, the user frequently finds its competitive advantage no longer holds and makes the new product available through license to manufacturers. As a matter of fact, almost the entire array of automatic analysis equipment developed in the last ten years was introduced to the market in this way.

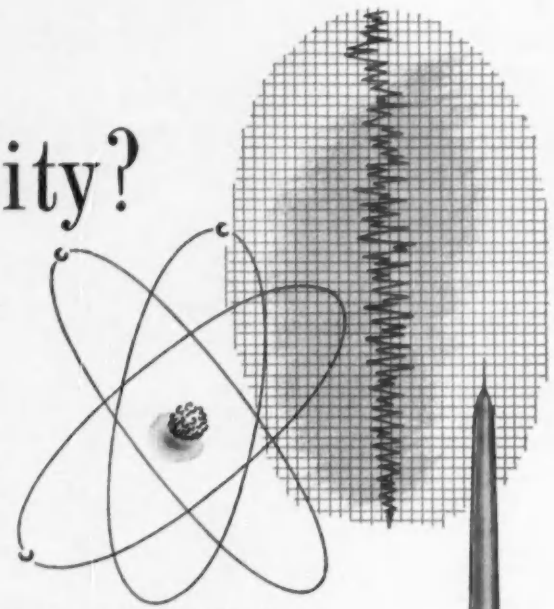
Aside from new developments to meet specific needs, we have frequently found it very profitable to extend the range of measurement or improve the performance of commercial instruments or control devices. Our findings are then, almost as a matter of course, passed back to the manufacturer for the benefit of other users. And because of our activity in instrument development we are often asked to assess the potential value of new devices that are either being considered for development or are about to be marketed. Sometimes we are actually successful in persuading the manufacturer to push a sorely needed product – or to spend its development money more wisely.

Cooperation by licensing designs, by passing on improvements, and by informal product consulting has been very rewarding. Maintained and broadened, it will continue to aid the growth of the instrument industry – and to meet the needs that shape our field.

Victor F. Hanson

*FIRST OF A SERIES*

# What is reliability?



**Industry in the United States is becoming more and more complex... we're getting automated ... computers are computing... the missiles are flying... the digits are digitizing...**

**And the word "Reliability" takes a new and different meaning... what does it mean to you?**

It's time to stop and take a look! Ask three of your friends how they define "reliability." You'll be surprised at the different answers you receive. And when you quiz them further on how much reliability is needed in a particular product... how they would control the design and manufacture of that product to obtain the amount of reliability they want... you'll be even more surprised by the variety of the answers.

So... let's define reliability. Let's start off with a definition that is gaining the most acceptance in the technical field...

***The reliability of a particular component or system of components is the probability that it will do what it is supposed to do under operating conditions for a specified operating time.***

Looks simple enough!

But what hazards it presents! The first important challenge is that word "probability"... it takes you seriously into the field of data collection and statistical analysis. Then you check into the phrase "do what it is supposed to do"... someone must define these objectives. And, look at the "operating conditions"... pause briefly and reflect on the many different conditions under which products operate. And, finally, note the phrase "for a specified operating time"... does one normally, consciously, define reliability in terms of time?

These considerations pose problems for all of us... the manufacturers of components, those who assemble components into other products, systems personnel, designers, industrial engineers, production workers, purchasing agents, quality control... *and users!*

Let's look at the word "probability."

Picture a chain, with its successive links. Many of today's systems, simple or complex, comprise such a chain of components. However, as we all know, that chain will be only as reliable as its weakest link. And, statistically, the over-all reliability of the chain or system is the mathematical product of the reliabilities of the individual links expressed as...

***Over-all Reliability,*** $R_o = r_1 \times r_2 \times r_3 \ldots r_n$

As an example, assume a product has a chain of 100 components in which each component has a reliability of 99 per cent... which assumes that only one out of a hundred units of each component will fail. These are relatively high standards established by past practices. But what happens? Multiplying .99 by itself one hundred times ($.99^{100}$), note that our chain of components will have a reliability of only 36.5 per cent! Two out of three of our chains would probably fail!

As another example, let's look at contacts in a multi-contact electric connector. If, for instance, we are to assemble connectors containing 25 similar contacts from a 1% defective contact population, we can expect 22% of the connector assemblies to contain one or more defective contacts! See how the multiplication of probabilities presents a major challenge to both designer and manufacturer?

But all is not lost! There is another side of the picture. With proper care, analysis, and control, our organization at Cannon has actually achieved, in special "missile quality" contacts, a known level of only $2.85 \times 10^{-3}$% defective... or one defective part in 35,000! Naturally, we don't achieve

that with all our contacts . . . but we do try to design and manufacture the utmost in reliability required for specific applications.

However, to return to your problems and to go a step further in demonstrating "probability" of uncontrolled contacts . . . and the challenges it poses to you and to us . . . consider the case where we have three groups of contacts, each group with contacts of different sizes. Let us assume, also, that each group has different percentage defective populations and that the three groups are assembled in a 90-contact connector as follows:

50 No. 16 contacts with a population reliability of .59;
25 No. 12 contacts, reliability .60; and 15 No. 8 contacts, reliability .64.

Then . . .

$$R_c \text{ (90 contact connector)} = r_{\#16} \times r_{\#12} \times r_{\#8}$$

or,

$$R_c \text{ (90 contact connector)} = (.59)\ (.60)\ (.64) = .23$$

It is apparent from the above that connector contact populations must be maintained at extremely low values of percentage defective. This is of extremely vital importance if we are to produce connector assemblies which will perform satisfactorily in systems utilizing series circuitry, where the failure of one contact pair can cause failure of the entire system.

We have been talking only about *a contact* . . . just one of the many different materials and parts (such as contact pins, insulators, shells, and couplings) going into the more than 20,000 different connector and electrical items we manufacture. Think of the "product of reliabilities" rule in systems comprised of tens, hundreds, or thousands of electrical components connected by connectors such as ours. Regardless of whether they design, manufacture, sell, or use washing machines or guided missiles, everyone faces the same problem. That's why we're taking some of your valuable time to present the important subject of reliability here.

*

All of us, when we specify materials, parts or components must constantly keep in mind the (a) "probabilities," (b) what the part is supposed to do, (c) the operating conditions, and (d) the time it must operate satisfactorily. Let's see what we can do to increase reliability in relation to these four factors:

***(a) Probabilities.*** To increase the reliability of any component, and thereby the system as a whole, it is necessary to think in terms of statistical distribution of important physical properties. From field reports of failure and laboratory test results, we must first isolate those properties which most frequently cause trouble. It is then necessary to determine whether poor performance is due to lack of process control to keep the product within specified tolerance limits, whether the dollar sign has entered into the picture too far—cutting reliability down for the sake of a few cents here or there—or whether the design itself is inadequate for an end-use application. In any case, the use of the statistical approach to problem solution offers a positive method of obtaining known levels of reliability.

***(b) Definition of Function of Product.*** Each component and each system . . . both civilian and military . . . in each different field of endeavor, in each product produced, has different functions. None of us should "overbuild" . . . nor should we "under-build." We should look at our specifications closely.

***(c) Operating Conditions.*** Temperature and pressure, humidity, corrosive atmospheres, stray electric and magnetic fields, low and high frequency noise, shock and vibration . . . all must be considered plus conditions prior to product use.

***(d) Operating Time.*** This varies both for different products and different fields of application. Have you set reasonable lengths of operating time for your product or system, from the viewpoints of both usage and economics?

*

We at Cannon Electric are proud of our historical emphasis on quality and reliability. Since our inception in 1915 we have consistently adhered to a design philosophy embracing the highest quality and reliability in each Cannon Plug for the specific application for which it is to be used. *If we cannot design to that principle, we don't make it!* In manufacture, we are proud of our know-how in depth, proud of our fine quality control systems, proud of our personnel, and proud of our reliability control group. The "Cannon Credo" . . . part and parcel of the everyday life of each Cannon employee . . . is posted in all offices and all departments of all eight Cannon plants around the world. Three of its sections read as follows:

***To develop an organization of exceptional people possessed of respect for the dignity of the individual and imbued with the spirit of the team.***

***To provide a facility with which we can produce to our utmost in an efficient and pleasant environment.***

***To develop and produce products of such quality, and render such service, that we may always be proud of our efforts.***

*

Whenever *you* have an electric connector reliability problem . . . in design, engineering, production or prototype phases . . . we would welcome the opportunity of discussing it with you.

*Cordially,*

Robert J. Cannon *President*

CANNON ELECTRIC COMPANY
3208 Humboldt St., Los Angeles 31, California

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*Eight plants around the seven seas!*

Complete coverage,

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# OSCILLATORS

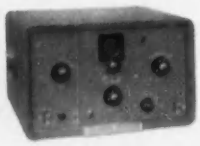
## 0.008 cps to 10 MC

Hewlett-Packard, pioneer of the now-standard resistance capacity or RC oscillator circuit, today offers 11 stable, wide range, RC oscillators covering all frequencies 0.008 cps to 10 MC. Each instrument is a precision, quality built equipment guaranteeing you highest stability, long term trouble free operation, and the convenience of compact size and wide frequency range. Brief specifications are given here; for complete details see your *-hp-* representative or write direct.

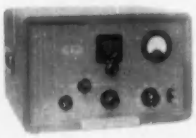
| Instrument | Primary Uses | Frequency Range | Output | Price |
|---|---|---|---|---|
| -hp- 200AB | Audio tests | 20 cps to 40 KC | 1 watt/24.5 v | $130.00 |
| -hp- 200CD | Audio and ultrasonic tests | 5 cps to 600 KC | 160 mw/20 v open circuit | 160.00 |
| -hp- 200J | Interpolation, frequency measurements | 6 cps to 6 KC | 100 mw/10 v | 225.00 |
| -hp- 200T | Telemetry, carrier current tests | 250 cps to 100 KC | 160 mw or 10 v/600 ohms; 20 v open circuit | 350.00 |
| -hp- 201C | High quality audio tests | 20 cps to 20 KC | 3 w/42.5 v | 250.00 |
| -hp- 202A | Low frequency measurements | .008 to 1200 cps | 20 mw/10 v | 465.00Δ |
| -hp- 202C | Low frequency measurements | ½ cps to 50 KC | 100 mw/10 v | 365.00Δ |
| -hp- 205AG | High power tests, gain measurements | 20 cps to 20 KC | 5 watts | 440.00Δ |
| -hp- 208A | High quality, high accuracy audio tests | 20 cps to 20 KC | + 15 dbm | 565.00Δ |
| -hp- 233A | Carrier test oscillator | 50 cps to 500 KC | 3 w/600 ohms | 475.00 |
| -hp- 650A | Wide range video tests | 10 cps to 10 MC | 15 mw/3 v | 490.00Δ |

### 3 of 11 famous *-hp-* oscillators

***-hp-* 200CD, 5 cps to 600 kc.** Probably America's fastest selling precision audio oscillator. Offers highest stability, constant output, year after year dependability. 5 ranges, frequency response ±1 db, distortion less than 0.5%. Compact, weighs only 22 lbs. 300° logarithmic dial, 60" effective scale length. $160.00.



***-hp-* 202A Low Frequency Function Generator.** Convenient, highly stable, multipurpose source of transient-free test voltages from 0.008 cps to 1,200 cps. 5 bands, distortion less than 1%, provides sine, square or triangular waveforms. 30 volts peak output, frequency response flat within 0.2 db. $465.00Δ.



***-hp-* 650A Test Oscillator.** Provides fast, accurate tests from 10 cps to 10 MC. Extreme stability; output flat within 1 db full range. Voltage range 0.00003 volts to 3 volts. Output impedance 600 ohms. No zero set, no adjustment during operation. Output voltage attenuator, self-contained VTVM. $490.00Δ.

ΔRack mounted instrument available for $15.00 less.

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## ELECTRONIC MEASURING INSTRUMENTS

# How a Systems Team Engineered a Plant Computer Test

**Management sets high goals for what plant control must eventually do: maximize profit, minimize maintenance, preserve continuity of operation, and increase productivity of products that meet ever-changing market specifications. The control engineer has the challenging job of meeting these goals with real-time automatic systems. Will he need equipment and technology not available today?**

**This article and its prologue, "Digital Computer Explores Real-Time Production Control", page 24, October issue of CONTROL ENGINEERING, go a long way toward answering the question. They demonstrate the problems encountered and the solutions found in engineering. Used in the solution:**

**an "internal" system of standard and developed equipment for measurement and transmission of plant variables—location Niagara Falls.**

**an "external" system that computes, with a general-purpose digital computer, production and yield rates from the transmitted plant variables—location Philadelphia.**

**▶display equipment—location Wilmington.**

**Next: use productivity and efficiency indices in continuous plant control.**

**E. W. James and J. Johnston Jr., Engineering Service Div., E. I. du Pont de Nemours & Co., Inc.**

**E. W. Yetter and M. A. Martin, Electronic Instrument Div., Burroughs Corp.**

One of the most promising steps toward automatic control for optimum productivity, or for other chosen plant and business operating criteria, is the adaptation of known electronic computer techniques to continuous computation of the criteria. It opens the way to a higher degree of process control through manipulating, in response to computed deviations from the selected criterion, the set points of present-day key-variable (level, temperature, flow, pressure, etc.) controllers to one best combination. Going a step further, it is not difficult to visualize a properly programmed computer that could completely supplant existing automatic controllers.

Computers can continuously solve equations in which all of the variables are changing with respect to time. For this, the equation is broken down to a number of operations, each requiring a computer program step. The number of such steps is limited only by the size of the memory system in the computer. Each step can encompass the complete operation of multiplication, addition, subtraction, differentiation, integration, etc. Computers already in use can do this. To be economically feasible, each measurement would have to be scanned and each control action taken so rapidly that the control loop would appear to be continuously active. Scanning systems under development are fast enough. Controller action based on the examination of several variables, instead of just one, would be possible. Furthermore, the controller actions could reflect either the statistical averages or trends of measured variables. Manipulation of the process to suit a predetermined schedule would be handled by a mathematical program rather than by rigid mechanical gears and cams. Startup, shutdown, and readjustment of the entire process sequence could be programmed to meet a wide variety of special criteria.

## Requirements

Electronic computer control of material processing will not come overnight. Its desirability is recognized, but requirements such as the following must be detailed first:

- ▶specifications, including the degree of accuracy necessary to obtain useful information
- ▶evaluation of the possibility of tying in standard industrial instruments
- ▶what form the production control information should take

To get a clearer picture of the requirements for computing, a team was formed to set up a long-distance real-time system. The team was composed

of technical, operational, and maintenance people from the Niagara Falls plant of the du Pont Company; computer programmers and mathematicians from the Burroughs Research Center; and instrument and communications engineers from the du Pont Engineering Department. The data chosen to satisfy the purpose of the program were used to compute the following information considered most helpful for the process operators:

1—Total raw material transferred into the process
2—Total production
3—Production rate in pounds per hour, averaged over each half-hour
4—Over-all yield
5—Yield rate averaged over each half-hour
6—Material balance and accumulated losses around the complete process and in each section of the process

## The process

The process chosen is typical of those in many chemical operations. It is small enough for the conduct of tests without large or complex instrumentation. As a complete chemical conversion occurs in the presence of a reactive agent there is considerable interest in the yield and material balances. Figure 1A is a flow diagram of the processing steps.

Basic raw material in liquid form is injected into two reactor units operated in parallel. Each reactor has a recycle stream to facilitate the chemical reaction without large storage capacity. There is provision for feeding the reactor units with either 100% pure raw material or reprocess material, which can vary between 30% and 70% purity. Pressure, temperature, and recycle flow rates are controlled automatically. Input material flow is controlled manually and the reacting gas input automatically to suit the required stoichiometric ratio. The vent losses are minor and are relieved through pressure control valves.

Pairs of tanks located throughout the process are used as surge tanks. During the test they also served as measuring tanks. While one was being filled the other of each pair was being emptied. Measurement of level change gave a measure of flow rates.

Reprocess material is collected for about seven hours while the process is operating on new raw material. The accumulation is then fed to the reactor for an hour. The switching of feed from new raw material to reprocess material seriously handicaps continuous data processing during the process transit time of one and one-half hours. This difficulty was partially offset by two factors:

- The total rate of charge to the reactor during the reprocessing period was adjusted to make the quantity equal to that fed when using new material.
- Discontinuities were minimized by the high ratio of reactor recycle stream to the reactor input stream.

## Engineering the system

Figure 1B shows the instrument arrangement. Ten liquid level measurements were made with standard dip tubes and pneumatic differential pressure transmitters. The output signal represented a measure of the hydrostatic head and was, therefore, read as the weight of liquid above the zero line of the dip tube. Reactor output composition was manually set into the system with a pressure regulator. A solenoid-operated valve installed in each of the eleven pneumatic signal lines was operated in sequence by a rotary selector switch driven by the synchronous motor of the Bristol Metameter telemetering transmitter. Thus each pneumatic signal was fed in turn to a manifold connected to the Metameter. Four of the signals were connected with such long lengths of pneumatic tubing that extra capacity in the system was used to repeat the transmission of these particular variables. This allowed the manifold pressure to reach equilibrium after the switching operation; only the second transmission was used in computation.

The Metameter has a transmitting switch which closes for a fraction of its operating cycle proportional to the value of the input pressure. The switch keyed a 1,000-cps oscillator, producing a train of pulses that was acoustically coupled to a leased telephone line by a small speaker adjacent to a standard telephone handset. The cycle time of the Metameter was 15 sec per measurement; of this, 3 sec was for balancing, 9 sec for data transmission, and the remaining 3 sec for transfer to the next signal.

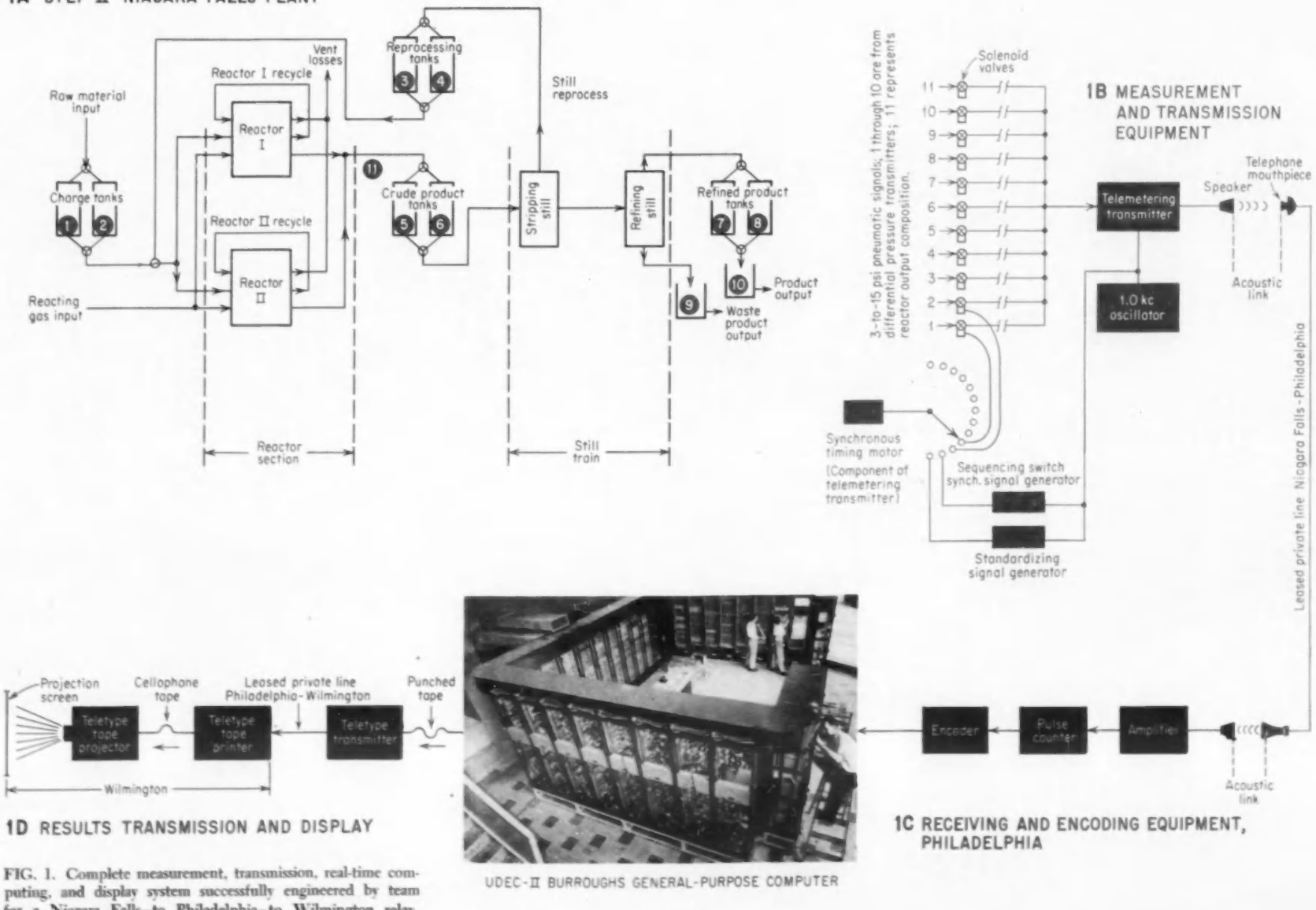
The equipment at the computer end of the telephone link, see Figure 1C, consisted of a microphone which received the output from the telephone, an amplifier, and a standard cycle counter. Accounting and coding circuitry were part of the computer.

Computed results were punched on teletype tape at the computer center. The tape actuated a teletype reader and transmitter connected to a leased line from Philadelphia to Wilmington. As shown by Figure 1D, at the Wilmington receiver the information was printed on transparent cellophane tape and projected on a screen by a tape projector similar to the type used with stock market ticker tape. At the end of each 6-min computing cycle, a new length of tape displayed the current production rates, yields, efficiency, and losses.

## Computation—accepting data

The computer was programmed to accept the input signal in the form of counted pulses. Every signal used at least 3,000 counts, except the synchronization signal which was always between 500 and 1,200 counts. The computer tested the successive input signals against these limits. As soon as a synchronization signal was detected, the computer accepted the remaining signals as part of the same batch.

To retain proper identification of each input signal in a batch, it was necessary that the computer accept only one input signal during each 15-sec transmission period. Accordingly the computer was programmed to so perform the computation that about




UDEC-II BURROUGHS GENERAL-PURPOSE COMPUTER

**FIG. 1. Complete measurement, transmission, real-time computing, and display system successfully engineered by team for a Niagara Falls–to Philadelphia–to Wilmington relay.**

14 sec out of the 15 available would have elapsed since the beginning of the signal transmission. If the transmission of the signal were interrupted and arrived as several signals, only the first part of the transmission would be accepted by the computer; hence only one number would be wrong in the batch of data. Incremental changes were compared against previous readings before the new value was inserted for computation. If the new value differed by 10% from the previous one, it was ignored and the previous value substituted. Single pulses were ignored; the computer recognized a signal as valid only if it contained at least four pulses.

### Computation—calculation of output

The eleven measured variables were enough to furnish material inventory change information in each stage of the process. Two different kinds of intermediate results were required:

1—cumulative material flows from time zero to the present and knowledge of material inventories at time zero and the present;

2—history of the process during the averaging time or just preceding the present.

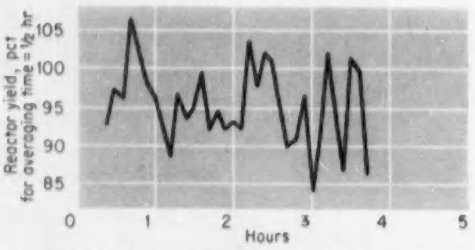



FIG. 2. Uncorrected reactor yield plotted directly from yield data displayed in Wilmington.

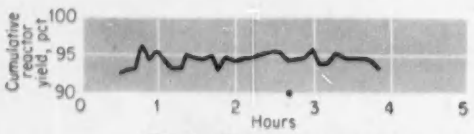



FIG. 3. History of computed cumulative reactor yield during four-hour run.

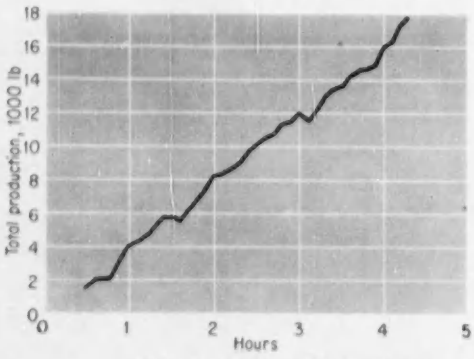



FIG. 4. Total production during run.

The instantaneous material inventories were determined directly from the current levels in each tank. To determine the cumulative material flows up to an instant, the incremental material flows since the previous computation cycle were calculated from the level changes in the various tanks, then added to the previous cumulative material flows. The material flows during the averaging time were then the difference between cumulative material flows at the instant and the cumulative material flows at the beginning of the averaging time.

In 20 sec the computer calculated the intermediate results and the other information listed under "Requirements". The results transmission and display system took an additional 15 sec for punching the teletype tape and 30 sec for printing. Thus the computer and display equipment used 65 sec out of an available 105 sec in the complete 6-min cycle. This contrasts sharply with similar computations made manually on the basis of an 8-hour shift average and available 24 hours later.

### Evaluation

General and spot improvements seen necessary were reported in last month's article.

Complete calculations made by the large-scale computer were duplicated for one run on a desk calculator. All of the final results thus computed agreed closely with the printed results. Hence the intermediate results were assumed to be correct.

In a detailed analysis of one run, the reactor losses curve plotted was so irregular that it was impossible to detect an average slope. The reactor yield curve, Figure 2, although irregular, showed a cumulative reactor yield, decreasing with time. Later it was realized that three times during the run appreciable quantities of raw material had been decanted from the charge tank. When the values of raw material and of unaccounted-for losses were reduced by the cumulative amount of decanted raw material, the losses curve became relatively straight. When the line was displaced to the origin, the cumulative reactor yield was nearly constant over the test period, see Figure 3.

For a study of the overall system operation the cumulative production and the cumulative useful raw material were plotted against time. The useful raw material behaved well, but as Figure 4 shows, the cumulative production curve was not smooth. The limit of accuracy for each level measurement was exceeded. Computations were made on quantities which should not have been associated; due to plant lag they did not relate.

The test proved the practicability of using intermediate-scale computers in the control of plant operations. The telemetering equipment was quite satisfactory. But before continuous control is tried, primary measuring instruments must have greater accuracy and must be applied more carefully.

# Differentiating Circuits— Tools for Industrial Control

**In your plant do you need to measure and control:**
**Metal rod diameter during rolling?**
**On-the-fly cropping of the nose and tail of rough slabs?**
**Drawn tube wall thickness and eccentricity?**
**The cooling of centrifugally cast pipe?**
**Or automatically detect:**
**Location of hot castings in the foundry?**
**Incorrect roller-bearing taper?**
**Thickness and concentricity of wire insulation?**
**Camber and twist of strip metal?**
**This article shows a basic approach that generalizes to meet such needs. It describes the necessary noncontacting measuring elements. And it explains differentiating circuits that operate on the measured signals to provide meter indications and to actuate motor controls, flying shears, water sprays, screw-down controls, deflectors, and blowers.**

**CARL A. VOSSBERG, Southeastern Electronic Laboratories**

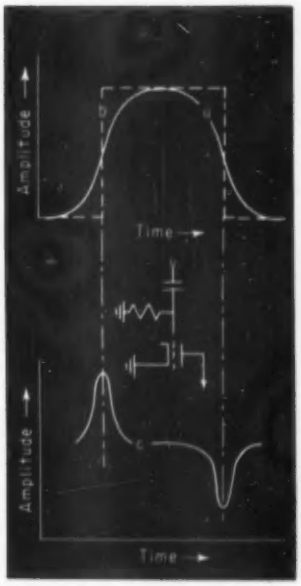



FIG. 1. R-C differentiating circuit responds to rate of change of actual signal, a, developed in measuring an object or happening that has the sharp physical demarcations shown by b. Curve c is the differentiator's output.

The signal produced by the measurement of an abruptly changing physical condition or situation cannot change instantaneously. It tends to round off and trail away. Accordingly, it is a problem to determine at what point in the signal to recognize the change. This problem can be solved rather easily by measuring the *rate* at which the condition is changing instead of measuring its *absolute value*. The device used is known as a differentiating circuit, getting its name from the fact that it produces an output proportional to the first time derivative of the input signal. Fortunately, its output is sharpest where a curve representing the signal's absolute value is most indefinite.

Solid line a, Figure 1, illustrates a signal produced by measuring, with radiation detection means, a physical event represented by broken line *b*. How wide is the signal? Apparently its width increases indefinitely as its amplitude decreases. Differentiating the signal with the circuit shown produces curve c, which is the slope or rate of change of curve *a*. Peaks in c occur when the maximum slopes of line *a* occur. Independent of the signal's amplitude, these peaks depend in time and amplitude only on how fast curve *a* is changing. The peaks can trigger flip-flops to generate a square wave that very nearly repeats the pattern of the original changing condition.

In Figure 1 the occurrence of the measured signal's maximum slope coincides with the instant at which the physical event occurs. When the measured signal's maximum slope is delayed, the square wave triggered by the action of the single differentiating

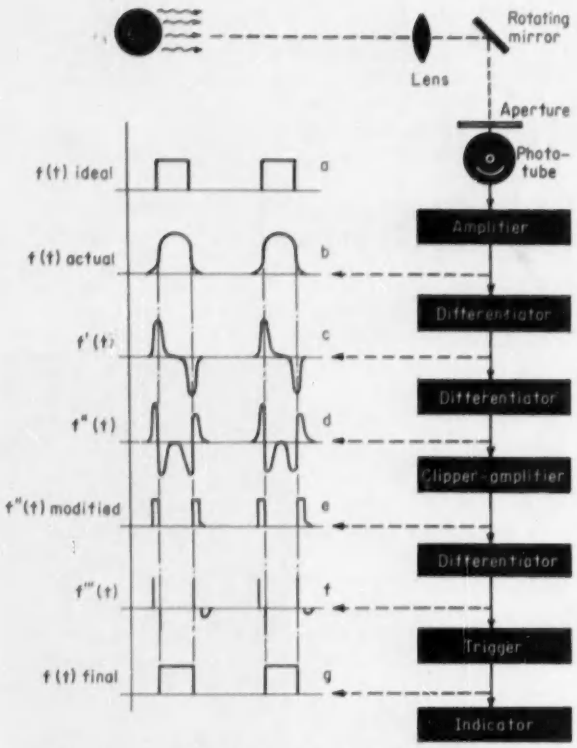



**FIG. 2. Noncontacting measurement of hot rod diameter. Differentiation, amplification, clipping, and triggering sharpen recognition of discontinuities.**

circuit will be delayed through the same time interval.

## SCANNING THE OBJECT'S IMAGE

Physical contact is either undesirable or impossible in many applications that require measurement of an object's linear dimension. The material may be hot, ductile, or abrasive or the required dimension inaccessible. Consider, for example, measuring the diameter of a hot rod while it is being formed. Figure 2 shows the situation. Passed through a lens, the rod's radiant energy forms an image on the aperture in front of the phototube. A rotating mirror scans the image along the measured dimension. An ideal measuring element would produce a signal with the rectangular wave shape indicated in Figure 2a. The time interval during which the radiation produced by the image impinges on the phototube would be a function of the measured dimension. Accordingly, during a complete scanning interval, the ratio of the image signal interval to the complete scanning interval would be a measure of the object's diameter independent of the scanning frequency.

Because of optical imperfections the image does not change abruptly at the boundaries of the rod, the phototube contributes distortion and lag, the radiated energy may not be uniform, and the aperture must necessarily be of finite width. All these effects cause departures from the ideal wave shape to an actual signal something like that shown in Figure 2b. It has gradually sloping sides. However, the points of maximum slope correspond, with considerable accuracy, to the boundaries of the original object. Differentiation of the signal delivers an output shown by Figure 2c. A second differentiation produces a signal shaped substantially as demonstrated by Figure 2d. Note that the two successive differentiations result in a wave shape that crosses the time axis at points corresponding to the maximum slopes of signal *b* and independent of the signal's amplitude. Signal wave *d*, applied to an amplifier-clipper stage, produces wave *e*. A third differentiator develops signal *f* which comprises sharp pulses that trigger a flip-flop stage, the output of which is *g*, a faithful production of the ideal signal *a*. A meter indicates the average current of signal *g* and thus the image dimension.

Since only the ratio of the rectangular wave duration to the complete scanning cycle duration determines the average magnitude of the current, changes in the scanning rate will not affect this magnitude. And variations in the image signal amplitude will not affect the measurement accuracy, i.e., will not alter the *points* of maximum slopes.

Such a system has found wide use in measuring, and at a distance of 15 ft, hot steel strip up to 100 in. wide.

Similar principles apply to measuring the concentricity of an insulated conductor. Figure 3 shows a conductor enclosed by insulating material. It moves continuously along its axis, as it would when manufactured. X-rays directed perpendicular to the wire axis cast a shadow of the wire onto a fluorescent screen. The shadow has a dense central portion produced by the metallic core and two outer, less dense, portions produced by the insulating covering. The treatment of the scanned shadow's image, similar to the image treatment in the rod gage, produces the wave shapes and pulse patterns shown by Figures 3i through 3m. Pulses shown in Figure 3n are measures of the insulator wall thickness on one side of the conductor and pulses shown in Figure 3o measures of insulator wall thickness on the opposite side. Figure 4 is the circuit diagram of the output section. Pulse patterns *n* and *o* indicate, again, the opposing wall thicknesses while the wave form at the third input to the circuit shows the synchronous blanking signals that remove spurious pulses. The three meters indicate the two wall thicknesses and the concentricity. Outside diameter of the wire, or the inside diameter of the core, could be indicated and recorded for product quality verification. In this case the gage would have to be calibrated as a comparator since the size of the image depends on its distance from the X-ray source.

## SCANNING THE OBJECT ITSELF

Instead of scanning, with a rotating mirror, the reflected or projected image of an object, the radiant

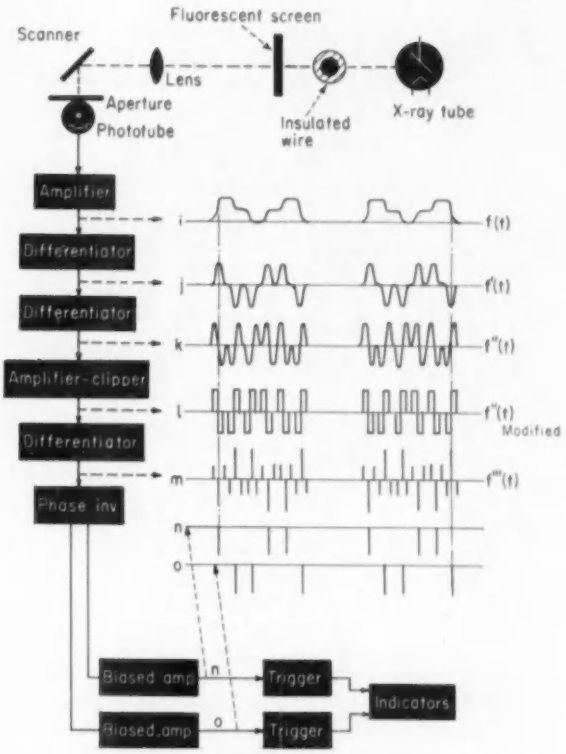



**FIG. 3. Noncontacting measurement of insulation thickness and concentricity.**

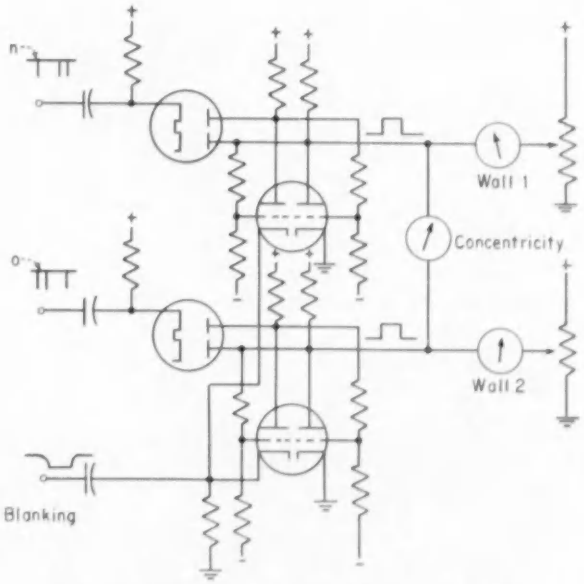



**FIG. 4. Circuit diagram of the thickness-concentricity gage.**

energy (X-rays, for instance) from the source can scan directly across the chords of a circular cross-section. The solid black line in Figure 5 is a plot of gross wall thickness across each chord of a ring. The curve has maximum slopes at the inside and outside wall surfaces. Scanning with X-rays perpendicular to the section axis produces a cyclic signal similar to the curve. By differentiating the signal, the maximum slopes can be detected and the wall thicknesses of opposite sides thus measured.

When the circular cross-section is made up of a ring and a core more dense than the ring, the center section of the plot rises along the colored line shown. The cyclic signal produced by scanning perpendicular to the cross-section is similar to the new plot. An interesting application is to the measurement of the gap between a steel artillery shell and a copper ring seated about it. The use of differentiators extends to almost any configuration that has sharp demarcations or abrupt changes in properties along the scanned dimension.

## APPLICATIONS TO PROCESS CONTROL

One process control uses an infrared detector which responds to a change in heat radiation caused by the presence or absence of hot bars. Ordinary ac-coupled amplifiers develop an actuating pulse that is a function of the rate-of-change of the radiation. As applications in iron foundries and steel mills meet severe dirt and atmospheric conditions, they impose a need for the utmost reliability. The instrument must operate satisfactorily without frequent lens cleaning. Such instruments have performed faithfully for years without preventive maintenance, even though the signal indicators are no longer visible under the accumulation of iron dust.

In other applications these rate-of-change infrared detectors operate water sprays, deflectors, blowers, blanking controls, and the like. The differentiators make operation independent of sensitivity and ambient conditions. By proper design the sensitivity can be a thousand times that required for adequate operation, allowing a wide margin for deterioration of the effecting signal.

In a hot steel mill the nose and tail of slabs leaving the roughing stand are rounded, forked, or jagged. As the irregular sections give trouble in subsequent operations they must be cut off on-the-fly with a rotary shear. A modified form of the infrared width gage measures the cross-sectional width at one point along the strip. This measurement is continuously compared with a like measurement taken by a second scanner located one foot down the strip.

▶ At the nose: When the magnitude of the first scanned width approaches the magnitude of the second, a command is transmitted to a computer which starts a timing sequence that takes into account, among other things, the velocity of the strip. A position transducer connected to the shear com-

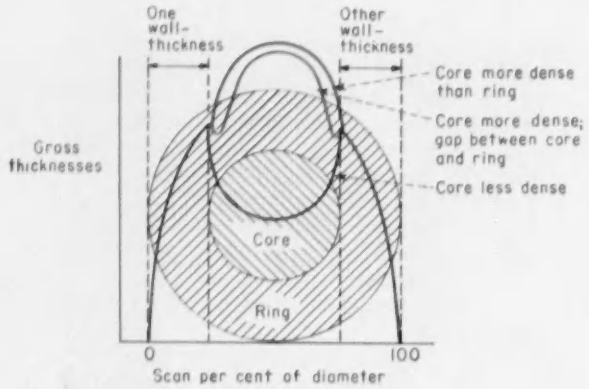



**FIG. 5. Plot of gross thickness across the chords of a circular cross-section.**

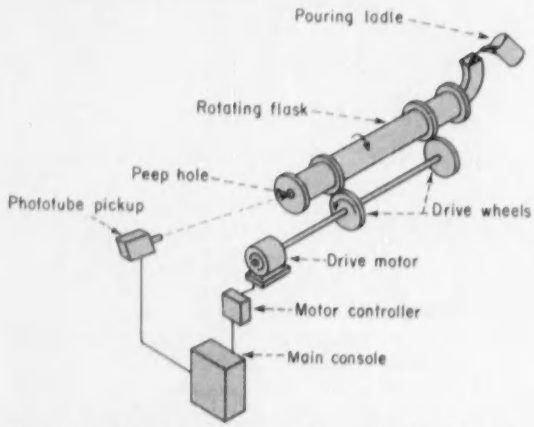



**FIG. 6. System completely controls centrifugal casting machine operation by measuring transitions between the solidification phases of casting.**

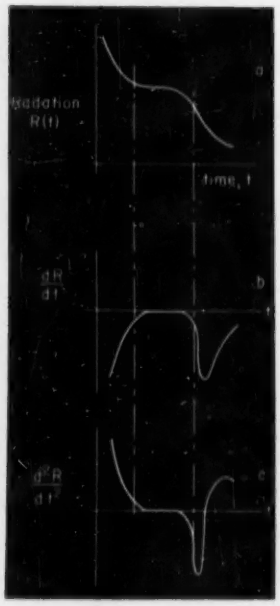
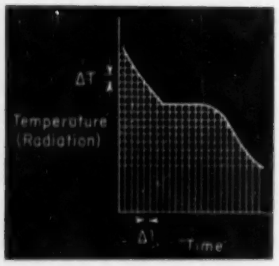



**FIG. 7. Cooling curve, a, determined by measuring the casting's radiation. Second derivative, c, of measured radiation triggers control relays.**

**FIG. 8. Cooling history divided into increments of temperature (radiation) and time.**




pares its instantaneous position with that required by the computer. The difference positions the shear so that it correctly crops the nose when triggered by the preset threshold of width difference.

► At the tail: The cropping signal is made when the second scanner accumulates an integrated measured width less than the first. A forked tail operates the trigger circuit too, causing the trigger to effectively consider that section as a radical departure from the nominal width. All measurements are independent of the strip's temperature. Water spots, scale, etc., which could mask the slab and cause a false triggering signal, are canceled out as the system resets itself when the signals assume original values.

Still another variation lends itself to measuring the camber or twisting of the strip as it leaves the mill. A very interesting application of time rate-of-change measurement occurs in the detection of solidification conditions in centrifugal casting machinery. Figure 6 is a perspective schematic view of the casting machinery and its motor controls. The freshly poured molten iron cools initially (first phase) at a relatively rapid rate, as shown by Figure 7a. When solidification commences, there is a marked decrease in the cooling rate because heat is generated during the exothermic solidification (second phase) of the iron. In fact, the radiation may actually increase. After solidification is complete, the temperature resumes its relatively rapid descent (third phase) until it reaches room temperature. During the last phase there is no risk of deforming the casting and the machinery can be stopped. It is the purpose of the system to detect the transition points between cooling phases and to slow or stop the machine accordingly. This avoids unnecessary wear on the machinery and increases pipe production without risk of deforming pipe.

Figure 7b is the first derivative of 7a and 7c is the second derivative. The two second-derivative peaks operate trigger circuits to slow the machinery during the solidification phase and to stop the entire operation when the casting enters the solid-cooling phase. The arrangement has a practical operating limitation. When the cycle extends over a period of minutes, the long time-base of the cooling curve makes capacitor-resistance differentiating networks impractical.

## MECHANICAL DIFFERENTIATION WITH TIMERS AND RELAYS

To overcome the short time constants of the usual differentiating circuit, discrete time and temperature increments are measured as a practical means of obtaining control signals from the cooling curve. The graph in Figure 8 illustrates the method. The time axis is divided into small but finite increments, $\Delta t$, and the corresponding temperature increments, $\Delta T$, are measured. Or, with fixed temperature increments, the corresponding changes in time intervals are determined.

As shown in Figure 9, the phototube output is compared with an adjustable balancing voltage by

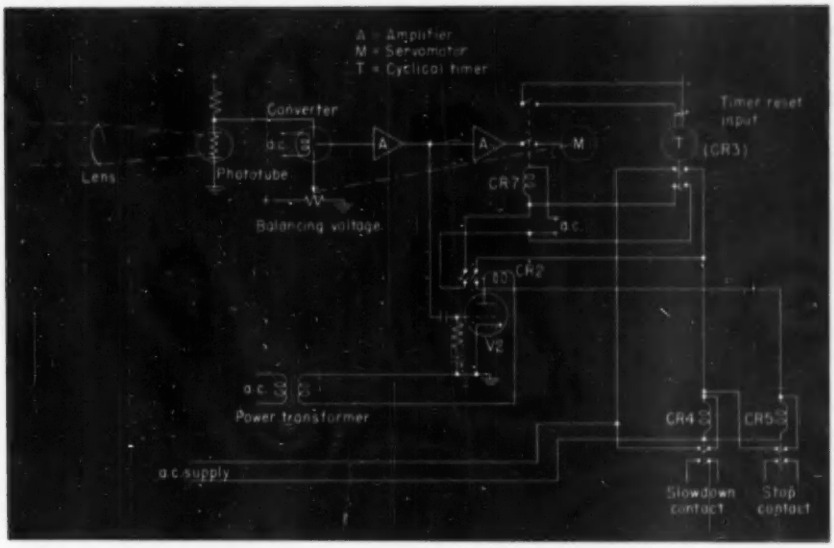
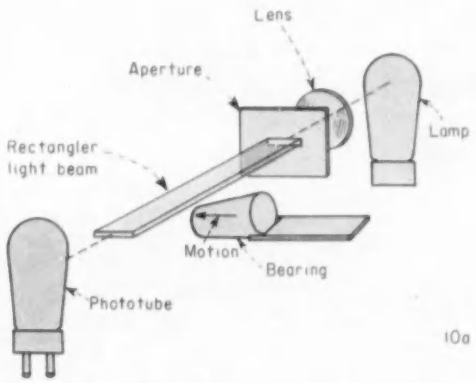



FIG. 9. When cooling consumes so much time that capacitor-resistor differentiating circuits are impractical, an electromechanical differentiator works on measured intervals of temperature or time to trigger control relays at cooling-curve transition points.



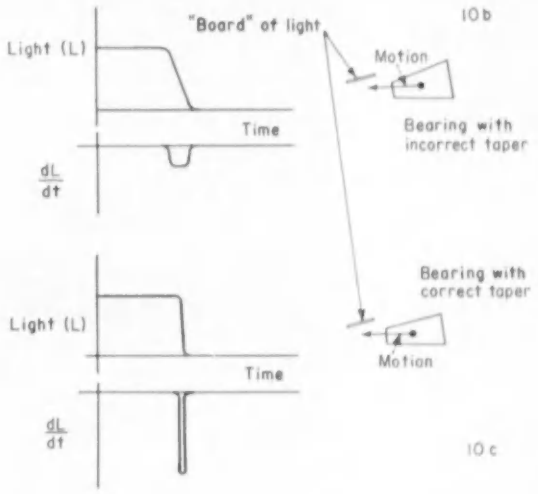




FIG. 10. Differentiated signals can discriminate between bearings with correct, c, and incorrect, b, tapers.

means of a chopper-converter. A cyclical timer periodically closes a circuit which completes a servo loop and the servo motor drives the adjustable reference voltage to balance the phototube output. During the first phase of the temperature run-down curve the error signal is sufficient to actuate the trigger circuit each time before the timer can time out. Operation of the trigger or timer resets the system to balance. However, upon reaching the plateau of the cooling curve, the signal is insufficient to fire the trigger and contact CR4 closes to slow the casting machinery. After the casting solidifies, the temperature again decreases rapidly, permitting the trigger to operate before a rebalance is made. This information actuates the controls which stop the casting machine.

Differentiators are feasible in contour-coincidence systems. For example, one may desire to check, without contact, the taper of roller bearings. The bearings pass, at a uniform speed, through a narrow "board" of light (Figure 10a) set at the angle of desired taper. Figure 10b shows the case for a bearing whose taper does not match the angle of the light beam. Because only one corner of this bearing blocks the light beam, the phototube output and its differentiated signal will be as shown. A bearing with the correct taper cuts the beam at all points simultaneously, causing the light signal to terminate abruptly when the bearing passes out of the beam. Figure 10c shows that the corresponding differentiated signal hits a sharp peak, indicating correct taper.

As an alternate, the width of the differentiated pulse signal can be measured. This is a function of the correctness of taper and is independent of optical and sensitivity variations. The simple scheme will not indicate which way the taper is in error, but it is not difficult to meet this requirement.

*Many features described in this article are protected by patents issued or pending. Publication in no way waives rights.*

# What to Consider When You Buy EDP

**When considering the use of electronic data-processing equipment, you must determine whether it will save your company money in cutting clerical costs, and decide whether improving management decisions will be the big payoff. These are not easy things to find out, and more than a superficial examination is necessary. Logical steps are to carefully define your objectives, investigate the available equipment possibilities, and run detailed cost analyses of the proposed systems versus your present system. There is a tendency today to reduce the time between the first thoughts of conversion and the purchase of the equipment by by-passing this procedure. This approach may have its merit, but if you follow the detailed costing process outlined by author Faulkner you are sure not to suffer as many pangs of pre-installation apprehension and post-installation difficulties.**

**CHARLES E. FAULKNER, Spiegel, Inc.**

There are many reasons for using electronic data-processing equipment, some valid and some not. Most important of the valid reasons is cost reduction potential. Progressive business organizations must direct their efforts toward cost reduction, and if electronic data-processing equipment will help, its use should be considered. Another valid reason is the reduction in process time, which means better customer service or faster action-information, both reflected in greater profits. There is also the definite possibility of obtaining more timely management information in more comprehensive form, again reflected in more profit, this time through better disposition of the company's facilities, reduced operating expense, better merchandising, and other such factors. However, it is generally better to consider these latter advantages as a bonus, above and beyond the operating cost reduction, because such collateral advantages have a habit of disappearing under the weight of negative factors, through no fault of the system or of themselves.

But some units have been installed or equipment has been ordered for reasons less valid than these. Publicity has been instrumental in some decisions. Other companies have installed for experimentation and research against the future. While the publicity may look good, and research may be well-justified, return to the stockholder is still the ultimate consideration. Installations are generally very expensive, even when rented, and the costs will be apparent if there is little or no return. The installation and use of electronic equipment require highly trained manpower and many hours; it's possible that this time and talent might yield greater results elsewhere.

Thus cost reductions or other means to increase profits must be the criteria for adopting electronic data processing. This implies a cost analysis. Although this may seem obvious, the fact is that to-date some installations have been made with no costing, or unrealistic costing, the result being a rude awakening when the equipment was put into operation.

Following the preliminary survey of the feasibility of an electronic system by an internal engineering staff or committee, or by a consulting group, a team should be set up to completely study, analyze, and recommend the action to be taken. Every effort should be made to avoid the pitfalls that others have encountered, some of which are listed in Table I.

A completely objective cost analysis must be predicated on three bases:

- complete delineation of objectives
- thorough investigation of equipment availabilities
- detailed operations analysis

## The system objectives

Clear statement of the system objectives involves studying and determining the desirable ends, ascer-

TABLE I

## WATCH OUT FOR THESE PITFALLS

**Don't let the magic of electronic data processing "steamroll" a decision.**

Electronic data processing has been pictured in very glowing terms. The urge to be first, in front of competition, can override the usual studies that would point out the borderline cost advantage that may actually be the case.

**Don't let publicity interests influence a decision.**

Installations for publicity purposes may also lead to rude awakenings, since flamboyant moves accompanying installation often burn bridges with very embarrassing or business-losing after-effects. Further, the publicity value is soon nil.

**Don't use "arm-chair engineering" to save time.**

Improper equipment estimates may result in increased space requirements. The need for a special floor, to say nothing of channeling in existing steel-reinforced floors, tile and plaster walls to the ceiling, a large-air-conditioning system, and other incidentals may also be overlooked. A few more people than estimated may be needed to punch cards, hustle tapes, or maintain equipment. And early accuracy reports may indicate that an expensive, and unanticipated, balancing operation is necessary to validate input media. So, the plumber is called back, new rooms are built, and the payroll soars.

**Don't select equipment hastily.**

Ill-suited equipment, procured through inadequate investigation, can result in early supplementation, premature replacement, or expensive backtracking. Insufficient coverage in the original installation will result in the call for more equipment to protect the investment incurred in alterations, engineering, and programming. Much equipment has been bought from the drawing board instead of the shelf. It is untried, and precious time after delivery is spent on debugging, modification, and head scratching. With proper investigation and costing techniques much of this can be avoided.

**Don't be led by "opportunity" savings.**

"Opportunity" savings are those obtained by comparing the cost under an improved process that provides **additional** results against the cost of obtaining these same results by using old methods. This is not valid, since the old methods would never have been used to obtain these results.

**Don't base savings calculations on man-hours only.**

A favorite criterion in discussing electronic data processing is the number of people or man-hours that an installation saves. However, even in its most conservative form the "how many people" method is faulty, since it overlooks many important cost factors on both sides. Prime among these is the subsidiary capital investment factor, usually very large in terms of dollars. The cost of air-conditioned rooms, special typewriters, bursting devices, and other such items is ignored. On a five year (or less) amortization basis, these can represent an appreciable annual expense. Subsidiary operating expense, from more expensive media and other factors, is often overlooked or assumed to balance out, with sad realization when the invoices begin to come in or the maintenance labor account doubles overnight.

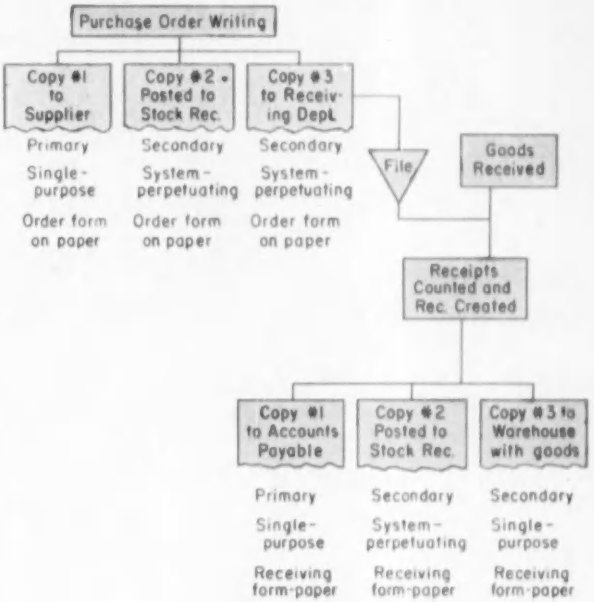



FIG. 1. Purchase orders and receipts in a conventional inventory control system.

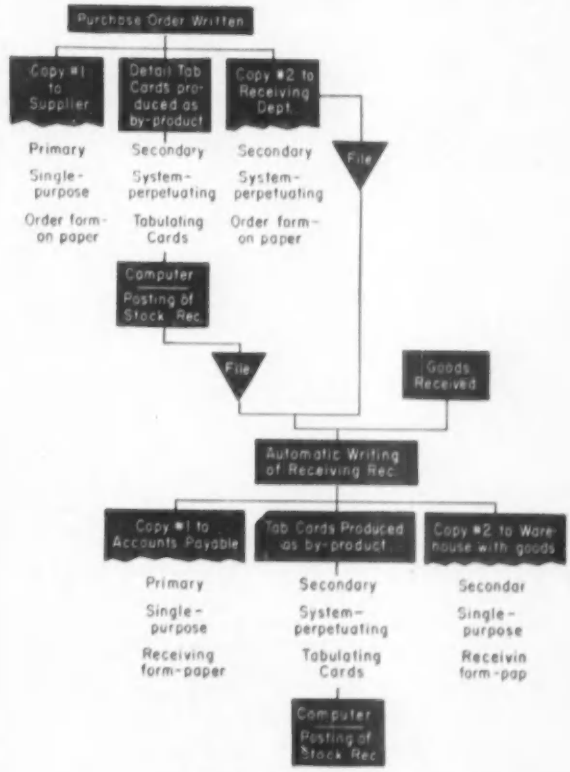



FIG. 2. This system functions the same as that shown in Figure 1, but uses tabulating cards as the system-perpetuating medium.

TABLE II

## COMPARISON OF PROCESS TIMES

| MANUAL METHOD | | TABULATING METHOD | |
|---|---|---|---|
| Totaling of tally strokes at rate of 4,000 strokes per employee hour—work distributed to 5 clerks. | 1 hr | Sort last 4,000 cards on 6 digits— | 0.8 hr |
| | | Collate 4,000 cards with previous 16,000 cards | 1.1 hr |
| | | Tabulate | 2.2 hr |
| Total process time | 1 hr | | 4.1 hr |
| Minimum process time on first units totaled | 0.1 hr | | 2.0 hr |

TABLE III

## COMPARISON FACTORS FOR DATA-PROCESSING EQUIPMENT

Internal memory capacity
Access time to internal memory
External memory capacity
Access time to external memory
Forms of external memory
"Commands" available (functions that computer and allied equipment can perform)
Available input forms
Available output forms
Output printing speed
Effective productive computer time
Maintenance requirements
Space requirements
Air-conditioning requirements
Operating personnel requirements
Number of units in the field and operating successfully

taining and fixing the perimeters, and planning the output and its use. Generally, electronic data-processing equipment is weighed for a particular operation, with the emphasis on the advantage that will accrue in one particular phase. For example, if applied to an inventory control system the intention will be savings in posting operations. Similarly, an insurance application will have the premium notice phase as its central consideration. However, these particular functions are only the high points in highly complex schemes of operations; complementary operations often involve many times the cost. Thus, a review is needed to determine:

1. *THE OUTPUTS*—whether they are primary or secondary, single-use or system-perpetuating, and their form and medium. Thus, the outputs for each area of operation must be classified to determine the required equipment, media, and method. For example, Figure 1 shows how purchase orders and receipts enter into an inventory control system. Note that the system-perpetuating documents proceed to points of manual transcription and then become dead. By using a system that produces cards or common language tapes, one document can be used repeatedly as the system-perpetuating medium, reducing manual transcription to a minimum. This is shown in Figure 2. These diagrams are over-simplified to show the document and manual transcription reductions that are evident in a very small sphere of operation. And with an increase in the scope of the operation, whether it is inventory control, insurance, utility billing, or another type of data processing, these economies become greater.

2. *THE INPUTS*—which must be classified in a similar manner, with a view toward automatic handling (for operating economy) and minimum human introduction of data (for accuracy). In Figure 2, the secondary output of the purchase order writing operation is the input for the receiving record preparation. This leads to operating economy (use of already prepared basic data) and accuracy (only one variable—quantity received—entered manually).

3. *THE MEMORIES OR DATA STORAGE DEVICES*—required by the system. These must be surveyed in the light of their purpose, form, cost of maintenance, and usability. All clerical systems consist of many memories or data-storage devices, although the minor memories are often overshadowed by the major and receive little consideration. And many times, the minor memories pose more problems, incur more cost, and are more difficult to integrate than the major memory. For example, a stock control system uses a straightforward major memory, consisting of stock on hand and the record of recent in and out transactions, with many stock-keeping units. Now say usage forecasting is desired in the system. The complexity of the variables required in the forecasting-data memory may so seriously tax the internal memory of the computer that the program will not be executed. In addition, the expense of maintaining the forecasting-data memory may be high enough to be prohibitive.

After preliminary investigations, perimeters must be fixed to eliminate the tendency to flounder about with the low-return phases and to permit going ahead in the maximum profit direction. This is similar to freezing specifications on a production model, although the engineers may still want to improve the prototype. Thus the general areas that lend themselves to electronics must be established early and fairly accurate savings forecasts must be made. In the case of the forecasting-data memory outlined above, the perimeter would be established around the stock control function, excluding the forecasting function, other factors being equal.

Strict attention must be given to the limitations imposed under electronic data processing. Many punched-card installations have appeared very favorable from a cost standpoint but have proved unfavorable from a process time standpoint; and similar limitations exist, in one form or another, with electronic methods. For example, take the substitution of a tabulating card system for the hand-tally method in recording 20,000 sales distributed among 1,200 stockkeeping units. It is very probable that the tabulating system would require so much process time in the summation that it would not provide the sales data as rapidly as the hand method. This is shown in Table II. Again, this is an over-simplified

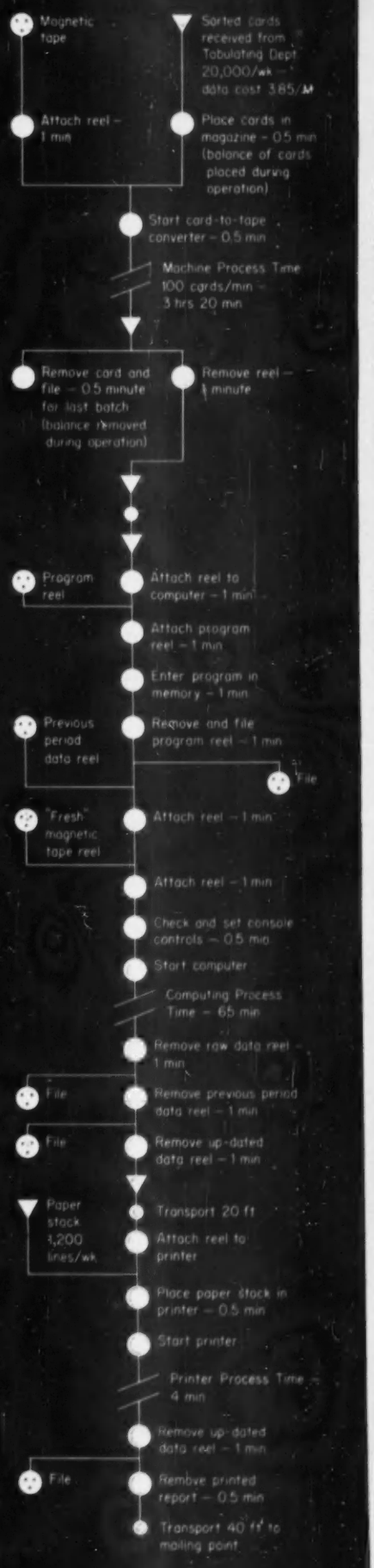



FIG. 3. Detailed Process Chart

example that does not attempt to take advantage of certain process time-reduction techniques sometimes applicable to tabulating methods. However, in this example, unless savings are so great as to preclude the process time considerations, the use of a card method cannot be considered.

## Equipment availability

Investigation of equipment availability has many facets. It begins with determining all possible sources. It has been estimated that there are from 100 to 500 legitimate manufacturers of data-processing equipment in the United States. Even if this is exaggerated, it would not be amiss to expect to be able to work with 25 to 50 manufacturers on a major project. Out of that number, the sources coming down to the wire may dwindle to ten or 12; but it is important to look at the equipment offered by all, because each has something not offered by the other and two or more may produce a combination that will fit right into the picture.

A careful study of the equipment is necessary. While comparison criteria depend on each particular application, there are several general factors that can be checked to evaluate the extent to which several

AUXILIARY EQUIPMENT REQUIREMENTS
EXCLUSIVE OF TABULATING EQUIPMENT

PROPOSAL BASIS Haley-Boyd Proposal #1

| Dept | Activity | Description of Equipment | # of Units | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| 212 | Media Prep | Electronic Typewriter Type Conversion | 3 | 45 | 135 |
| | | #1250 Multiliths | 4 | 3,500 | 14,000 |
| | | Racks | 10 | 55 | 550 |
| | Computing Center | Equipment Room | 1 | | 12,000 |
| | | Air Conditioning | | | 5,200 |
| | | Tape Storage Files | 5 | 81 | 405 |
| | | Maintenance Equipment | | | 2,750 |

FIG. 4. Itemized listing and costs of required subsidiary equipment.

**TABLE IV**

**COST OF COMPUTING CENTER PERSONNEL**

| Capacity | Cost Per Year Shift #1 | Shift #2 | Shift #3 |
|---|---|---|---|
| Manager | $7,200 | | |
| Shift Supervisor | 6,000 | 6,000 | |
| Computer Operator | 4,800 | 4,800 | |
| Printing Machine Operator | | 4,200 | 4,200 |
| Tape Librarian | 3,600 | 3,600 | |
| Maintenance-Operating -Preventive | 4,800 | 4,800 | 4,800 |
| Programmer | 4,200 | | |
| Totals | $30,600 | $23,400 | $9,000 |

manufacturers meet specifications. Some of these are listed in Table III. Each of these factors, and others besides, has a bearing on cost, and all must be thoroughly analyzed and interpreted in dollars and cents to verify a manufacturer's claims.

Two of these factors are accuracy and reliability. No general rules can be written on this subject, since the requirements vary from application to application. Definite differences in the construction and self-checking facilities of the various computers provide varying margins of error expectancy. Needless to say, the narrower the error margin, the greater the investment. The requirement for 99.9 percent accuracy as opposed to 99.5 percent accuracy must be weighed against the additional investment.

At the same time that the available equipment is being surveyed, the project specifications should be prepared and submitted to the likeliest manufacturers. This should be followed by orientation visits by the manufacturers' engineering representatives. This orientation, usually conducted by application or electronics engineers, could develop into a complete applications study.

In the interim, an analysis of present operations, flow process charts, process time schedules, media, volume records, production, overhead factors, and all other items that affect cost should be completed by the purchaser's staff for a complete comparison.

The various proposals should be evaluated with respect to:

- proposed equipment
- proposed processes

This evaluation must include adaptability to the present methods and facilities. The "tail wagging the dog" character of a proposal can very well rule it out immediately, or at least result in suggestion for revision. Adaptability to operations flow is another basic requirement. The entire operating structure of an organization need not and should not require complete change to obtain the anticipated savings. In some instances, appreciable changes may be required, but the savings must be consistent with the expense of these changes.

The most important consideration is: does the proposal fulfill the objectives? Each output must conform to the desired data product and must be obtained within the required process time, while equipment cost must fit somewhere in the range that preliminary studies indicated was reasonable.

## Operations analysis

After the preliminary studies have shaken out the unreasonable proposals, complete process flow charts should be developed for the systems outlined in the remaining proposals. To be effective, the process charts must be detailed enough to reveal every element of process cost. The typical chart shown in Figure 3 indicates required personnel time, equipment, supplies, and media. From such a chart, pertinent data can be developed as follows:

1. *PERSONNEL REQUIREMENTS*—First determine anticipated operations, personnel, and the hourly rates involved in the proposed systems. This should include all supervisory and other indirect labor factors. Actually, the time values shown in Figure 3 would not be translated directly into costs, since the operation portrayed is only one of many that would be processed through a computing center in a week's time. The final personnel costs might be broken down like those in Table IV. Needless to say, this table is hypothetical.

2. *REQUIRED SUBSIDIARY EQUIPMENT*—This refers to equipment that must be purchased or rented to facilitate operation, feed the data-processing equipment, and provide proper maintenance. For example, card processing may continue to be intrinsic to the system, thereby requiring the rental of card punches, sorters, etc., from a tabulating equipment manufacturer. This also applies to typewriters, paper-tape actuated devices, etc. Figure 4 itemizes this equipment (exclusive of rented tabulating equipment) for a typical proposal.

3. *REVAMPING PHYSICAL FACILITIES*—The reconstruction and installation necessary to house the equipment, provide for proper work flow, etc., can be heavy. Specially constructed rooms, platforms, and acoustical ceilings are often only the beginning. Extensive electrical provisions, with stand-by power, are axiomatic. Most computers require external air conditioning, although some

TABLE V **PROCESS TIME TABLE**

| Equipment | Shift #1 | Shift #2 | Shift #3 |
|---|---|---|---|
| CARD-TO-TAPE CONVERTER #1 | A B | | |
| CARD-TO-TAPE CONVERTER #2 | A A | | |
| COMPUTER | A | B C | Preventive Maintenance |
| PRINTER #1 | | A | C |
| PRINTER #2 | | A | B C |

COST SCHEDULE # H37A2A — PREPARED BY: J.J.

COST FACTOR DEPT. # 241 — ACTIVITY Return Goods Detail Cards — CHECKED BY: F.M.

| LABOR OPERATION | ANNUAL BASE UNITS | STANDARD PRODUCTION RATE | ANNUAL HOURS | HOURLY WAGE RATE | ANNUAL COST |
|---|---|---|---|---|---|
| Key Punch | 5,304,000KS | 7,500/hr | 728 | $1.25 | $910.00 |
| Verify Punch | 5,304,000KS | 7,500/hr | 728 | 1.25 | 910.00 |
| | | | | | |
| | | | | | |
| SUBTOTAL | | | 1456 | | 1820.00 |
| SUBSIDIARY OPERATION @ % TO | | | | | |
| DEPARTMENTAL OVERHEAD @ 21.5% | | | 313 | 1.20 | 376.00 |
| REMARKS | | | | TOTAL | $2196.00 |

| SUPPLY ITEMS | ANN'L BASE UNITS | WASTE % | TOTAL ANN'L UNITS | COST PER M | TOTAL ANN'L COST |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| REMARKS | | | | | |

| SUPPLY ITEMS | ANN'L BASE UNITS | WASTE % | TOTAL ANN'L UNITS | COST PER M | TOTAL ANN'L COST |
|---|---|---|---|---|---|
| Tab Cards | 156 M | 5% | 165 M | $1.20 | $200. |
| | | | | | |
| | | | | | |
| | | | | TOTAL | $200. |

| MACHINE RENTAL | EST. MACH MO'S | RENT PER MO | ANN'L TOTAL | FED TAX | PEAK EQPT. FRT. | TOT. AN'L COST |
|---|---|---|---|---|---|---|
| Key Punch | 14 | 35.00 | 490. | 49. | 10. | 549. |
| Verify Punch | 14 | 40.00 | 560. | 56. | 10. | 626. |
| | | | | | | |
| | | | | | | |
| REMARKS | | | | | | |

| MACHINE RENTAL | EST MACH MO'S | RENT PER MO | ANN'L TOTAL | FED TAX | PEAK EQPT. FRT. | TOTAL ANN'L COST |
|---|---|---|---|---|---|---|
| # 604 Operating Expense charged to | | | | | | |
| Center @ rate of $4.00 hr. - 52 hrs. | | | | | | 208. |
| | | | | | | |
| | | | | | | |
| | | | | TOTAL | | 1383. |
| | | | | GRAND TOTAL | | $3897. |

FIG. 5. Detailed cost sheet for labor, supplies, and rented equipment. This covers the costs for one activity in the system specified in one proposal.

provide it internally, but even these require additional electrical and plumbing work. Dust can affect performance, so that dust controls are often necessary. Other factors, too, must be considered.

4. *OPERATING SUPPLIES AND FORMS*—Determine the nature, quantities, and costs of the operating supplies and forms that will be required in the proposed operations.

5. *PROCESS TIME*—Develop process time tables of the operations, using the quantities of equipment recommended in the proposals.

Data-processor running time can either be taken from estimates submitted by the manufacturers, or (this is preferable) determined by at least partially programming each data-processor for the specific operations under consideration. Estimated running times should be calculated in the light of the optimum use of the individual characteristics of each data-processor. From the sample Table V, it can be observed that the computer requires 5½ hours on Job A, 4½ hours on Job B, and 5 hours on Job C; and the Job A work is available from the card-to-tape converters 2 hours after the start of the first shift. It completes Job A near the end of that shift, and printing can be started at the beginning of the second shift. This is the earliest reasonable time because of the small amount of printing work available during the first shift.

Certain clarifications or proposal adjustments resulting from the preceding evaluations will probably be necessary. The detailed costing processes involving the present and proposed operations follow, objectives being:

1. *LABOR COST*—This is the base of the cost comparison and must include all the operations in the present and each proposed system. In each case, the items affecting cost are volume, operating standards, wage rates, and overhead factors. Operations not directly in the flow, such as media preparation activities, summarizing, duplicating, and others that contribute to the product and its cost must also be included. Since savings are best determined on an annual basis, labor costs should be computed on the same basis.

To simplify control of the cost compilations, set up a detailed cost sheet for each activity and establish a set of identifying symbols for proper indexing. Then the completeness of each set of costings can be cross-checked. Figure 5 shows a typical detailed cost sheet, the upper tabulation devoted to labor costs in the Return Goods Detail Cards activity.

2. *FORM AND SUPPLY COSTS*—On the same detail form, Figure 5, must be space for analyzing the forms and supplies used, including volume and unit costs, and the total annual costs.

3. *RENTALS*—Where rental equipment is

COST SUMMARY RECORD

PAGE 8 OF 8

PROPOSAL SPECIFICS

| COMPUTER EQPMT. MFR. | BASIC MEDIA | BASIC METHOD | METHOD ALTERNATIVES |
|---|---|---|---|
| Haley-Boyd Computer Co. | [X] Tab Cards<br>[ ] Paper | [ ] Pre-Shipment Billing<br>[X] Post Shipment Billing | [X] Auto. Credit Check<br>[ ] Manual Cr. Check |

| DEPT. | ACTIVITY | COST SCHDL. * | ANNUAL LABOR COSTS | ANNUAL SUPPLY COSTS | ANNUAL MACHINE RENTAL | ANNUAL MISC. COSTS | TOTAL ANNUAL COSTS |
|---|---|---|---|---|---|---|---|
| 212 | Sales Media Prep | V1A1A | 41,900. | | | | $41,900. |
| 212 | Sales Card Typing | V2A1A | 2,400. | 1,100. | | | 3,500. |
| 212 | Sales Card Printing | L3A1A | 11,600. | 47,500. | | | 59,100. |
| 212 | Master Pre-Punching | H4A2A | 400. | 50. | 1,050. | | 1,500. |
| 212 | Gang Punching | V6A1A | 5,500. | | 2,900. | | 7,900. |
| 212 | Reserve Storage | | | | | | 20,000. |
| 212 | Tub File | | | | | | 76,000. |
| 212 | Edit | | | | | | |
| 212 | | | | | | | |
| 212 | | | | | | | |
| 212 | Anal | | | | | | |
| 212 | Hold F | | | | | | |
| 212 | General | | | | | | |
| 212 | Tally | | | | | | |
| 241 | Receiving | | | | | | |
| 241 | Return Goods Detail Cards | N37A2A | 2,200. | 200. | 3,900. | | 6,300. |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | TOTAL $ | | 325,200. | 64,500. | 25,400. | | 415,100 |
| | GRAND TOTAL $ | | 2,651,300. | 163,700. | 76,800. | | 2,891,800 |

FIG. 6. Complete cost summary record for one proposal.

SAVINGS SUMMARY **PROPOSAL: HALEY-BOYD #1**

| Item | Present System | Proposed System |
|---|---|---|
| Labor | $3,169,300 | $2,651,300 |
| Supplies | 93,700 | 163,700 |
| Rentals | 300 | 76,800 |
| TOTAL COSTS | $3,263,300 | $2,891,800 |
| SAVINGS | | 371,500 |
| Personnel Expense Reduction @ 4% of Labor Savings | | 20,700 |
| Social Security Tax Reduction @ 1.8% | | 9,300 |
| Outside Services Eliminated | | 33,000 |
| TOTAL ESTIMATED ANNUAL SAVINGS | | 434,500 |
| 5 YEAR SAVINGS | | 2,172,500 |
| Prime Equipment | | 400,000 |
| Auxiliary Equipment and Building Alterations | | 75,000 |
| TOTAL | | 475,000 |
| Equipment Maintenance Costs—5 years | | 100,000 |
| Engineering and Conversion Costs | | 150,000 |
| TOTAL EQUIPMENT AND INSTALLATION COSTS | | 725,000 |
| NET SAVINGS—5 YEARS | | 1,447,500 |
| AVERAGE ANNUAL SAVINGS BEFORE FED. TAX | | 289,500 |
| RETURN ON CAPITAL INVESTMENT—ANNUAL | | 61% |
| AVERAGE ANNUAL SAVINGS AFTER FED. TAX OF $30,000 | | 283,500 |
| RETURN ON CAPITAL INVESTMENT | | 56% |

FIG. 7. A final savings summary, comparing the costs of the present system with the costs of one proposed system.

required, it should be itemized and costed on the same detail sheet. Particular attention must be given to the peak period requirements.

After the detail costs are computed and summarized (on a form such as shown in Figure 6), the operating savings can be determined by comparing the total annual costs of the various proposed systems and equipment with the cost of the present system. Certain collateral savings can then be developed and added to the total annual savings to obtain the gross operating savings. Such things as reductions in social security and unemployment premium payment, personnel expense (procurement, insurance, payroll preparation, benefits), expense of outside services (service bureaus, etc.), and other items are included in this factor. This procedure is followed on the Savings Summary in Figure 7.

Then the annual cost of the capital investment and equipment maintenance must be deducted from the gross operating savings for each proposal. A reasonable, acceptable amortization period must be selected, this period possibly differing between proposals. Generally, the amortization period may be shorter than that used for standard office equipment because of the obsolescence and reliability factors. However, the length of this period also depends on whether it is thought that the proposed equipment will provide returns that will obviate consideration of later improved equipments.

After selecting the amortization period, the annual cost of the basic and subsidiary capital investments can be determined. Coupled to this must be the annual maintenance cost, determined by a service contract offered by the manufacturer or a best estimate of maintenance labor and supplies. Maintenance expense will be appreciable in any system and must not be ignored.

Maintenance of rented equipment is usually included in the rental price. If the equipment is purchased, the manufacturer usually quotes at about 5 percent of the purchase price per year, including all costs of personnel and replacement parts. Although there is little evidence at this time, a self-sustained maintenance department will probably cost from 2½ to 4 percent per year.

Circumstances can decide whether engineering and conversion costs should be included in the computations. In some instances, the entire engineering cost must be charged against the installation. But if an engineering staff is maintained that incurs the same expenses on comparatively minor projects as on a major program of this nature, it is reasonable to disregard this expense. Conversion labor costs should be charged when they are over and above normal operating costs. As a by-product, incidental savings may accrue in activities that are outside the scope of the project.

In analyzing the cost of present operations, there is some question as to whether the capital equipment and the maintenance costs incurred by it should be included. They should be included if rented equipment is being replaced, but inclusion is questionable if owned capital equipment does not command a respectable disposal price.

With these data it is possible to develop the anticipated net savings and the percentage return on the investment. Two bases can be used:

1. Net annual savings during amortization period.
2. Net annual savings for a reasonable period longer than amortization.

Although amortization may be achieved in "x" years, a major electronic installation would undoubtedly be operated beyond this period. As mentioned previously, although improved equipment may become available, it doesn't necessarily follow that the original equipment will be replaced, since the improved equipment may not provide sufficient additional return to justify the added investment. This has proved true in many pre-electronic instances, and will continue to be true regardless of the current talk that equipment is obsolete before the first unit is delivered. Therefore, in calculating the annual savings for a period longer than the amortization period, only the anticipated maintenance expense for the additional years need be assessed against the gross savings for these years. Thus, the net average annual savings will be appreciably higher.

Heed one other word of caution. Federal Excise Tax rulings exempt computers and certain peripheral equipment. Be sure that equipment price quotations specify the amount of tax that will be charged to you for those items that will not be exempt.

In the final evaluation, the comparative savings between the several proposals are the major considerations. However, the proposals must also be considered in the light of several other factors that may or may not affect the final decision. First of these is the group of collateral savings that will be developed but that do not provide any basis for monetary evaluation. Examples may be the better service obtained in an order-handling system, the earlier issuance of checks in a payroll system, anticipated reduction of complaints through improved accuracy, better shrinkage control, and others. Different proposals may yield different results, all of which must be evaluated as objectively as possible to complete the analysis.

The equipment manufacturers must also be scrutinized. A good reputation is a prime requisite but not a complete endorsement. Stability and production progress are essential for getting the prospective purchaser into the user category at the earliest reasonable time. Successfully operating equipment in the field is probably one of the best criteria, and other installations of the proposed equipment should be visited before making a decision.

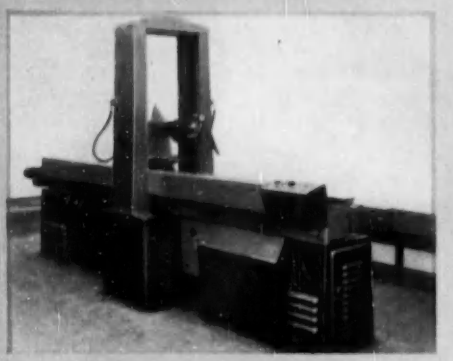
Undoubtedly, each application is influenced by factors not discussed above. These must be considered just as objectively as the costing process itself. They are all part of the cost analysis.

# Inspecting Missile Airfoils Automatically:

## Can Similar Techniques Solve Your Critical Inspection Problems?

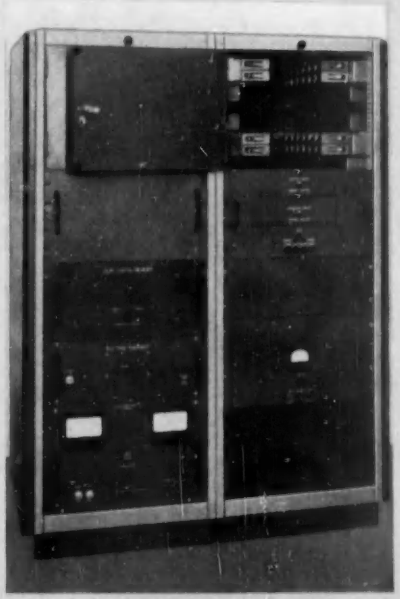
E. L. WATKINS, Convair, Pomona

**FIG. 1. COMPONENTS OF THE AERODYNAMIC SURFACE ANALYZER**



a. The airfoil positioner assembly. Airfoil is held in carriage that is servo-driven back and forth on horizontal ways. Vertical positioning servo simultaneously moves both digital transducers (one on each side of airfoil) up and down on vertical ways located in overhead frame. Pneumatic cylinders drive transducers into contact with airfoil.

b. Operator's console. Punched-tape input unit for complete system is at left, output printers are in center, and operator control panel is at right. Provision is made for automatic operation and certain manual operations, such as slewing the horizontal and vertical servos and some printer functions.



c. Control cabinet. Horizontal- and vertical-servo power supplies and amplifiers are in cabinet at right, while digital and analog computing equipment and auxiliaries are at left.

**THE GIST:** Certain types of missile systems using multiple stage propulsion must fly without guidance during the initial flight phase. To assure optimum conditions in the later phases, deviation from the ballistic path must be held to a minimum. Since the airfoil control shafts are positioned at dead center by their respective servomechanisms during this initial flight, the airfoil aerodynamic characteristics are the major factors influencing the steering. Problems in airfoil manufacture have forced the use of extensive inspection procedures to provide a reasonable yield of satisfactory airfoils. Originally, inspections were manual; now they are automatic, space integration techniques determining the effective incidence and camber of control surfaces.

There is a direct labor saving of 15:1. The manual method involved special tooling and used desk calculators to compute aerodynamic data in a factory operation. These measurements required 0.7 hour per piece, and sometimes two men performed redundant operations on one piece. The machine processes the same part in 0.1 hour or less, checks more points, improves data accuracy by a factor of 3, and eliminates intentional and accidental errors introduced by hand tabulation and calculation. Raw castings can also be inspected prior to machining, permitting a saving in scrapped parts.

Control is by punched tape, using binary input commands. Measurements are made with optical-type binary transducers, and a hybrid digital-analog-digital computer is used for computing and tabulating process data. Author Watkins covers the complete system; the details of the digital measuring equipment are given in "Measure Position Digitally", page 107.

## THE PROBLEM

During the initial flight stage of a missile, the control surfaces must not contribute any aerodynamic forces that will cause deviation from a true ballistic course. Thus, the movable control surfaces are positioned at dead center by their respective servomechanisms. But since the servo follow-up information is obtained from the control shaft and not the actual airfoil position, the major factors influencing steering are the amounts of dihedral, effective incidence, and camber of the airfoils. Figure 2 and the following, define these characteristics:

▶ **Dihedral** is the angle of inclination of the airfoil with respect to a transverse line, tangent to the missile body at the point of attachment, Figure 2A. In a missile having symmetrical surface configurations, dihedral produces rolling moments under maneuvering with combined pitch and yaw.

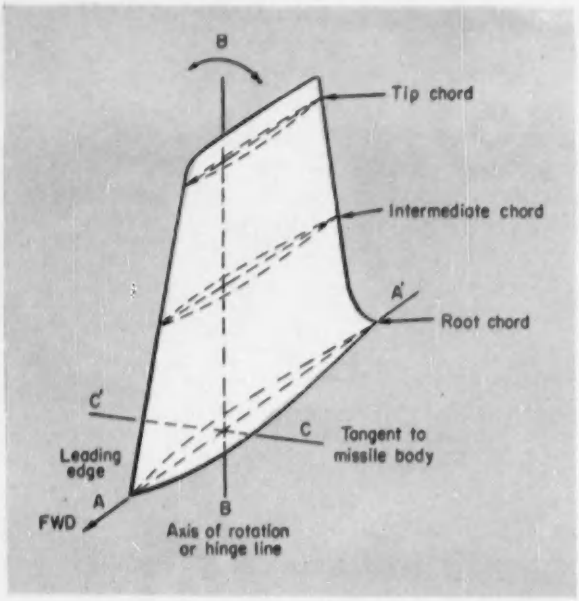
▶ **Camber** is the amount of curvature in the actual median line of the airfoil, Figure 2B. It increases the hinge moment, thus increasing the load on the missile control servo. This is a second-order effect during the initial flight phase and may force the control surface from zero, causing the missile to deviate from its prescribed course.

▶ **Incidence** is the difference between the angle of attack of a control surface and the angle of attack of the missile airframe. During the initial flight phase the angle of incidence of both the fixed and controllable surfaces should be zero; in other words, the angular location of the mean aerodynamic center of all surfaces should coincide with the median line of the missile body. A perfect airfoil's aerodynamic center should also coincide with its own median line. If incidence is present, however, the missile will deviate from its prescribed ballistic path, Figure 2C. Incidence also produces a bending moment in the airframe that prevents separation of an expended propulsion unit. The maximum allowable angular deviation may be as low as 36 min, with an allowable setting error of plus or minus 3 min.

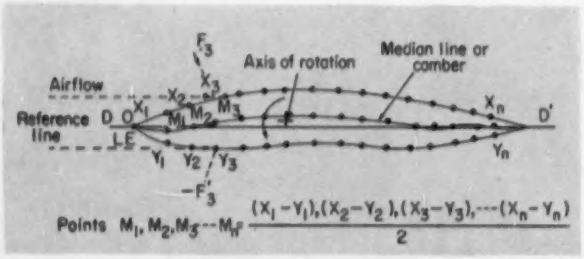
The problem of producing "perfect" airfoils on a mass-production basis is insurmountable. Known techniques of casting, forging, machining, and sheet metal fabrication cannot produce these devices with less than plus or minus 3 min of incidence. These same methods also yield some twist or camber, and dihedral in any airfoil. A reasonable production yield can be obtained, however, by determining the aerodynamic characteristics for small areas of the airfoil surface and integrating them to obtain the total for the whole surface. As a result of this integrating technique, imperfect airfoils can be used if the amounts of total incidence, camber, and dihedral are within specified tolerances.

To offset the effect of incidence, an indexing pin, located along a line passing through the force equi-

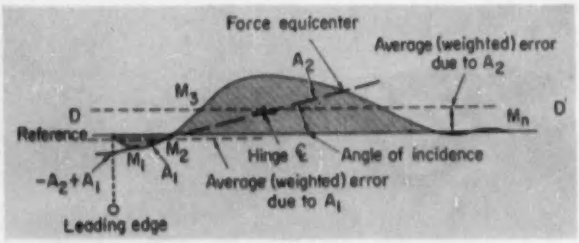
FIG. 2.
AIRFOIL AERODYNAMIC CHARACTERISTICS




A. Dihedral. A-A', B-B', and C-C' are three mutually perpendicular axes. Dihedral results from the angular deflection from B-B', using A-A' as the axis.




B. Camber. Cross-section shows exaggerated camber on one chord of warped casting. X and Y are distances at points 1, 2, 3, . . . n with respect to reference line D-D'. Point $M_n$ on median line can be computed knowing X and Y values.




C. Incidence. Force diagram shows angle of incidence of one chord. This can also be computed if distance from reference to airfoil surface for many points along chord is known.

center (Figure 2C), is used to position the aerodynamic center with respect to the missile servo system or missile body.

This inspection process involves determining the total camber and incidence for the entire surface. These parameters are checked along selected chord lines, and each local value is weighted and algebraically summed to obtain the total.

In the manual inspection process, data taken with an alligator gage are hand tabulated and later used in the solution of two separate equations, which are solved with the aid of a desk calculator. Two men inspect each airfoil to reduce the possibility of introducing natural or intentional errors. Measurement accuracy is within plus or minus 0.003 in. The inspection sequence is shown in Figure 3A, and the production yield versus the number of check points in Figure 3B. The average elapsed time per airfoil is 0.7 hour. With each missile requiring 12 airfoils, conventional tools can support moderate production rates. But any large increase in production would require the following:

- duplicate tooling—as many as four types of airfoils may be used on one missile, each using a different set of tools
- a large, specially trained labor force
- a large area to contain the labor force, tools, and material handling equipment.

A more practical solution to the production rate problem appeared to be some form of machine computing system. An analysis of the process established the following objectives:

- rate increase to 10 to 12 pieces per hour
- basic accuracy increase of 3:1
- removal of the human element—measuring and data computation to be done by automatic programming and automatic computing
- inherent flexibility for handling production changes to be provided

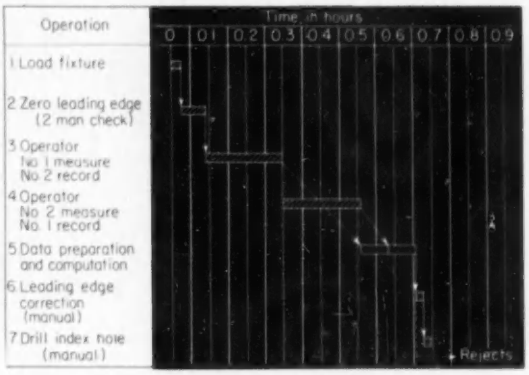
## THE SOLUTION

A development program, started in April 1955, culminated in the design of the Aerodynamic Surface Analyzer. This machine, Figure 1, automatically measures airfoil dissymmetry at preselected points, feeding its data into a computer that determines the local camber and incidence for the area represented by any one point. Each computation is tabulated by the machine, along with special data indicating the amount of dihedral. At the end of the process, the operator is presented with the values of dihedral, total effective camber, and incidence. A self-check by the machine indicates proper overall system operation. If a malfunction is detected, a simple monitoring procedure isolates the fault in one of the major sections of the system.

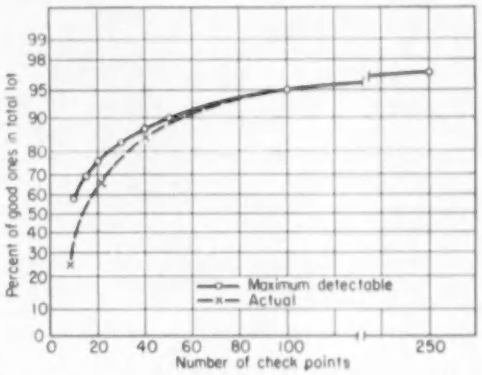
The processed data are used by the operator to determine product quality as follows:

1. The total effective camber value is checked

FIG. 3. INSPECTING MANUALLY




A. Manual inspection sequence showing time for each step. Note that both operators check the important operations, such as steps 2, 3 and 4. If both operators do not agree on steps 3 and 4, these are repeated. Since they are time-consuming, errors here could substantially increase cycle time.




B. Production yield versus number of check-points. Note that total yield goes up as number of check-points increases because isolated inaccuracies average out. For the same reason, actual approaches maximum-detectable as operator errors average out.

against a specified maximum for that particular type of airfoil.

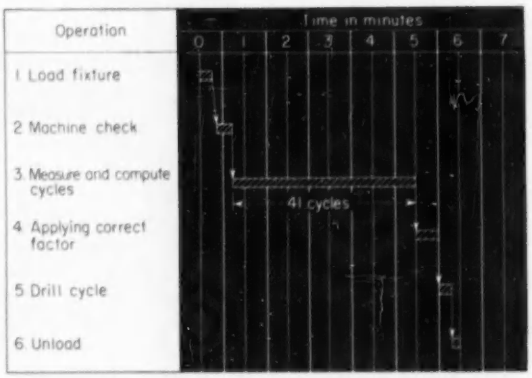
2. The total effective incidence factor is also checked against a specified maximum value. If acceptable, it is used to determine the location of the indexing hole. The angular correction for incidence is applied manually by the operator, using the machine's internal instrumentation. The airfoil is then automatically positioned for drilling the hole.

Six seconds are required to locate, measure, compute, tabulate, and store the results for any one point. Normal machine inspection involves 40 points per airfoil, so the complete process takes 5 to 6 min, depending on the size of the airfoil. The complete machine sequence is shown in Figure 4A, while Figure 4B shows the detailed sequence for one operational cycle. Setup time required to change the machine so that it can inspect a different type airfoil is 15 min, including changing the holding fixture, gun drill, and program tape, and changing the speed and feed of the automatic drill.

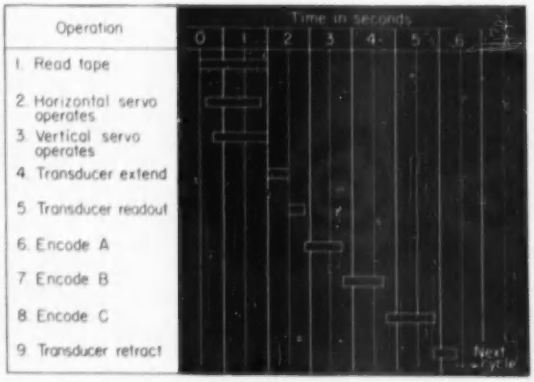
## The inspection system

Figure 5 is a functional diagram of the machine system. All machine operations are controlled by punched tape and a fixed sequence programmer. The tape contains: coded data for the location of any point in two planes, the multiplier constants used in computing the values of local camber and incidence, printer command signals for identifying certains items of tabulated data, and other special commands for the internal memory of the computer. The input data, in binary code, occupy seven channels of an eight-channel tape. The eighth channel (synchronizing channel) is used in cross-

FIG. 4. INSPECTING AUTOMATICALLY




A. Machine inspection sequence. Total time for average airfoil is about 6 min. Most of the time is consumed in measuring and computing. Only one operator is required.




B. Time sequence for one measuring and computing cycle. This is repeated 41 times in each total machine sequence as shown in Figure 4A.

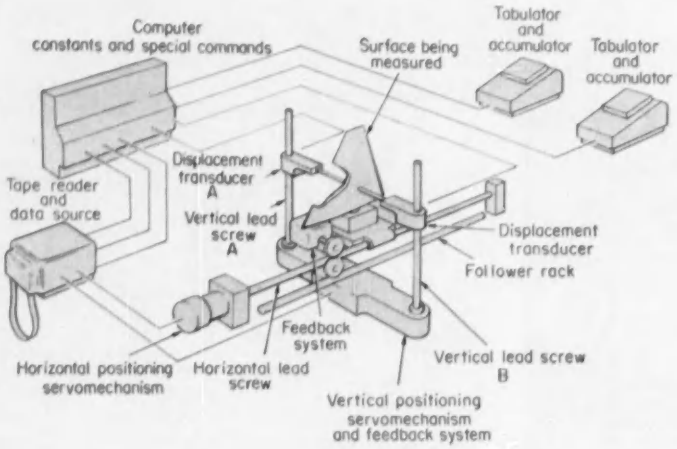



**FIG. 5. Functional diagram of complete system, except for automatic incidence-correction and drilling equipment. Horizontal system drives through precision rack, vertical system through precision lead screw.**

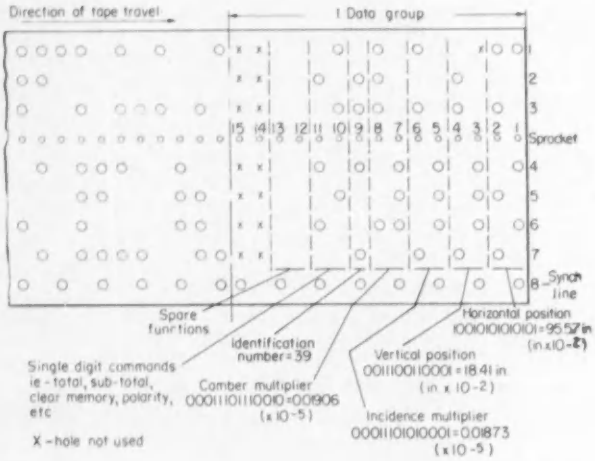



**FIG. 6. Punched-tape coding for programming inspection and computing sequence. Since all variable data are included on the tape, the system can be adapted for a different airfoil simply by using a new tape.**

checking the tape position with the data-sorter position. The tape reader will stop if an out-of-step condition occurs, thus stopping all machine operations.

Figure 6 shows a typical punched-tape format. The tape reader reads data groups of 15 rows at one time. The 14th and 15th rows are not used. The first two rows, each with seven channels, furnish the 14 binary digits that specify horizontal position to two decimal places (note that the decimal equivalent of the binary number must be multiplied by a factor of $10^{-2}$ to properly place the decimal point; similar factors are used with the other coded numbers). The third and fourth rows furnish the 13 binary bits necessary to specify vertical position, while the fifth and sixth rows and the seventh and eighth rows carry the binary-coded incidence and camber multipliers. The ninth row identifies the point being inspected, and the 10th and 11th rows furnish computer commands. With this code arrangement, 16 groups of data made up of 77 bits are fed into the machine at one time, the groups ranging in size from 14 bits to only one bit. A typical tape is about 60 in. long, fashioned in a continuous loop for repetitive operation. For long operating life, 5-mil mylar film is used instead of paper.

The system also includes a keyboard and tape punch. These are used to prepare new tapes or to reproduce worn tapes from previously cut masters. The program tape is prepared by hand, and since production changes are infrequent, programming time is insignificant.

## Positioning servos

Two independent servos position the airfoil and the measuring transducers. They are of the two-speed type and have a rectilinear positioning accuracy to plus or minus 0.005 in. Linear ball-bushings and ball-bearing lead screws are used to reduce friction. The horizontal ways are flame-hardened and parallel within 0.001 in. When an error in position exists in either servo, interlocking control signals are supplied to the fixed sequence programmer, stopping every machine function except the tape input and data sorter.

Figure 7 shows a functional block diagram of one of the servo systems. The total travel in both systems is divided into 5.12-in. segments. The five most significant binary digits in the horizontal input data, $2^{10}$ to $2^{14}$, ( or the four most significant in vertical data, $2^{10}$ to $2^{13}$) select the segment in which

the servo is to be positioned. The binary-to-decimal matrix and segment selector at the top of Figure 7 convert the coded information into polarity-sensitive error voltages at the output taps of the segment selector, delivering an error voltage to the mixer and power amplifier until the servo-motor has driven the follow-up gears into the proper segment. This is the coarse servo control. While a coarse error voltage is present, the coarse/fine speed selector prevents the fine servo control from operating.

When the coarse servo is nulled, the fine servo takes over. The remainder of the binary-coded data is converted to an equivalent analog voltage in the binary-to-analog converter. Then a conventional potentiometer-positioning system positions the load within plus or minus 0.005 in. of its commanded position. To avoid using the follow-up potentiometers near the end of their windings, two units (odd and even) are used in each servo. These are mechanically phased 180 deg and are selected by the $2^9$ digit. When both the horizontal and vertical servos have been driven to their nulls, the servo null detector signals the internal programmer that the positioning phase is completed and the transducers can be driven in against the airfoil, starting the computing cycle.

The horizontal carriage positioning servo has a total travel of 81 in., maximum velocity of 4 in./sec, working with a 300-lb load. The vertical transducer positioning servo has a total travel of 36 in., maximum velocity of 2 in./sec, working with a 50-lb load.

Lead screws in both systems preclude the effects of load inertia in the servo transfer function. Thus modest servo performance is obtained with a time constant on the order of 0.1 sec. Special precautions, however, are required to avoid damage to the equipment when running into mechanical stops.

An Excello-type automatic drill, enclosed in the positioner assembly, has been modified to operate in a vertical plane. Tungsten-carbide gun drills are used for a combination drilling and reaming operation. A drill bushing is in each airfoil holding fixture.

Quill advancement without rotation is accomplished by using an external hydraulic pump assembly. This technique permits a floating chuck to accommodate the plus-or-minus-0.005-in. positioning error of the carriage without damaging a high-speed rotating drill (or its bushing) by engaging the drill within the bushing in a stationary condition.

## The computer

Figure 8A gives a functional block diagram of the computer, the general equation which it solves, and the meaning of this equation in terms of an airfoil chordal section. Computations are carried out through a hybrid combination of digital-analog-digital techniques, with all digital information contained in the form of relay contact closures. Data are converted from digital to analog form by precision-resistor matrices associated with these relays, and all operations involving addition, subtraction, and multiplication are performed by analog methods. The analog data are then converted back to numerical form for tabulation and accumulation by the printers.

Briefly, the computing system functions this way: Binary input information from the two transducers is converted into analog signals in the two binary-controlled resistor circuits, and then subtracted and stored in the decimal matrix. The decimal matrix is adjusted to the proper value by the internal closed-loop system, using a step actuator. The input

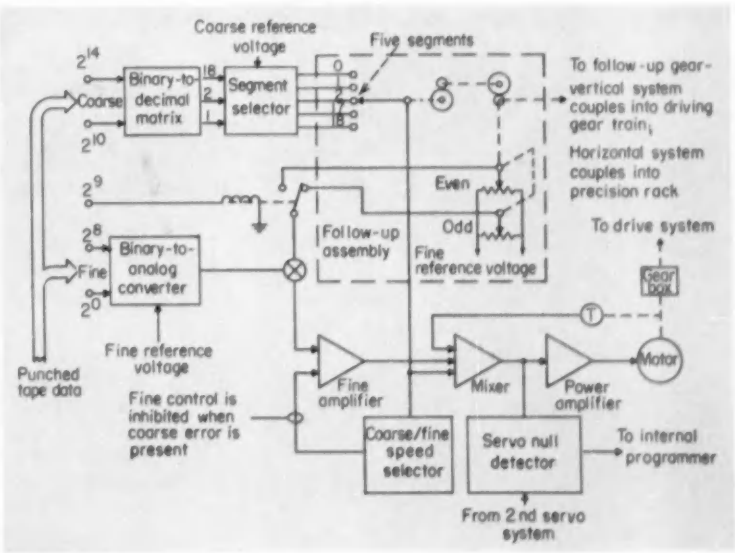
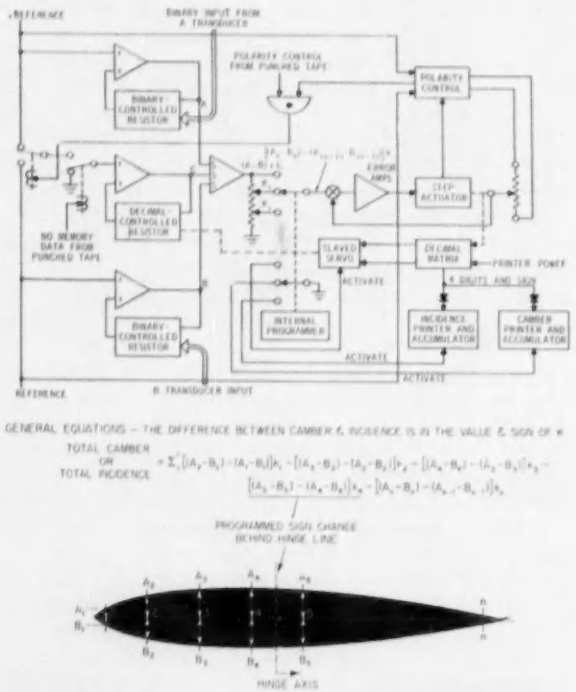



**FIG. 7. Two-speed positioning system for horizontal drive. Vertical drive circuitry is similar except that coarse servo includes only four segments.**




GENERAL EQUATIONS — THE DIFFERENCE BETWEEN CAMBER & INCIDENCE IS IN THE VALUE & SIGN OF K

TOTAL CAMBER OR TOTAL INCIDENCE $= \Sigma_1^n [(A_1-B_1)-(A_1-B_1)]k_1 + [(A_2-B_2)-(A_1-B_1)]k_2 = [(A_3-B_3)-(A_2-B_2)]k_3 + [(A_4-B_4)-(A_3-B_3)]k_4 + [(A_5-B_5)-(A_4-B_4)]k_5 + [(A_n-B_n)-(A_{n-1}-B_{n-1})]k_n$




DIHEDRAL MEASUREMENTS CONSIST OF A–B DATA TAKEN SPANWISE ALONG THE HINGE LINE. DATA ARE TABULATED WITH THE INCIDENCE RECORD AND SEPARATELY IDENTIFIED.

## FIG. 8. THE COMPUTING SYSTEM

**A. Block diagram of computing system, and the general equation solved by this system.**

**B. The step-by-step computing sequence for one chord of an airfoil.**

| LOCATION | | INPUT DATA | ENCODE | MEMORY | PRINT | ACCUMULATE | SPECIAL SYMBOL |
|---|---|---|---|---|---|---|---|
| 1 | c | $(A_1-B_1)$ | $(A_1-B_1) \rightarrow \underline{(A_1-B_1)}$ | YES (1 & 2) | NO | | NONE |
| | a & b | OMITTED | | | | | |
| 2 | a | $(A_2-B_2)$ | $[(A_2-B_2)-(A_1-B_1)]k_2$ | NO | YES ① | YES ① | W |
| | b | do | $[(A_2-B_2)-(A_1-B_1)]k_c$ | NO | YES ② | YES ② | W |
| | c | do | $(A_2-B_2) \rightarrow \underline{(A_2-B_2)}$ | NO | NO | NO | NONE |
| 3 | a | $(A_3-B_3)$ | $[(A_3-B_3)-(A_2-B_2)]k_3$ | NO | YES ① | YES ① | W |
| | b | do | $[(A_3-B_3)-(A_2-B_2)]k_c$ | NO | YES ② | YES ② | W |
| | c | do | $(A_3-B_3) \rightarrow \underline{(A_3-B_3)}$ | NO | NO | NO | NONE |
| 4 | a | $(A_4-B_4)$ | $[(A_4-B_4)-(A_3-B_3)]k_4$ | NO | YES ① | YES ① | D |
| | b | do | $[(A_4-B_4)-(A_3-B_3)]k_c$ | NO | YES ② | YES ② | D |
| | c | do | $(A_4-B_4) \rightarrow \underline{(A_4-B_4)}$ | YES ① | NO | | D |
| 5 | a | $(A_5-B_5)$ | $[(A_5-B_5)+(A_4-B_4)]k_5$ | NO | YES ① | YES ① | W |
| | b | do | $[(A_5-B_5)+(A_4-B_4)]k_c$ | NO | YES ② | YES ② | W |
| | c | do | $(A_5-B_5) \rightarrow \underline{(A_5-B_5)}$ | NO | NO | NO | NONE |
| n | a | $(A_n-B_n)$ | $[(A_n-B_n)+(A_{n-1}-B_{n-1})]k_n$ | NO | YES ① | YES ① | W |
| | b | do | $[(A_n-B_n)+(A_{n-1}-B_{n-1})]k_c$ | NO | YES ② | YES ② | W |
| | c | | | NO | SUB-TOTAL | NO | S |

NOMENCLATURE
① PRINTER NO. 1 W = WING
② PRINTER NO. 2 D = DIHEDRAL PT.

to this closed loop is the output of the summing amplifier which subtracted the transducer outputs. After the decimal matrix has been adjusted, the internal programmer activates the correct printer and accumulator. The initial stored value $(A_1 - B_1)$ is converted to an analog signal by means of the slaved servo and the decimal-controlled resistor network. The slaved servo, which is the internal memory, is activated by the internal programmer after the printing operation is completed, starting the next computing cycle, in which the next A and B signals from the transducers are subtracted and stored in the decimal matrix. Then the previous value, stored in the decimal-controlled resistor network, is subtracted from or added to the latest difference and multiplied by the proper constant ($k_c$ or $k_i$) giving the local incidence or camber. The latest difference value is then transferred to the decimal-controlled resistor network, and the local incidence or camber value is fed into the decimal matrix and printed out. Polarities in the computing networks are controlled by signals from the punched tape. The computer sequence for one chord of an airfoil is shown in Figure 8B.

The largest value of $(A - B)$ that the computer can handle is equivalent to 0.5 in.; however, the inputs rarely exceed 0.1 in. under normal conditions. The computational accuracy required is one part in 500. Large accumulative errors are avoided in the input and memory networks, multipliers, and analog-to-digital converter by holding individual errors to 0.025 percent for networks and 0.1 percent for the converter.

Since the equations of camber and incidence are identical in form (except for the value and sign of $k$), the computer is time-shared to allow solution of both equations. The increased time, due to time-sharing, does not presently restrict the process rate objectives stated earlier.

### Displacement transducers

The measuring heads consist of linear digital transducers using an optical encoding system and a pneumatic cylinder for extending and retracting the measuring probe. The output of the transducer is a 13-bit binary number in the form of relay closures. The least significant bit is equivalent to 0.0005 in., and the total travel of the scale in this application is 2.5 in. For further information on these transducers, see the following article.

The author would like to thank Bill Hopper and Dominic Rutland for assisting in the development of this system. They designed the circuits and mechanical portions of the analyzer.

# Measure Position Digitally

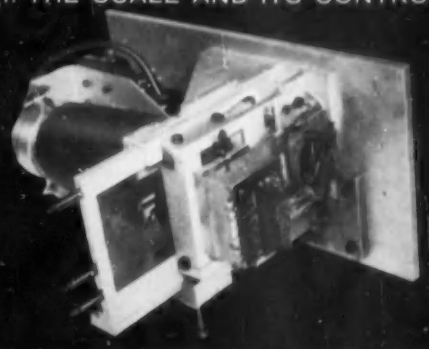
**WALDO H. KLIEVER, Consultant***

* The early development work on this transducer was accomplished while Dr. Kliever was vice-president and director of instrument development at the Clevite Research Center.

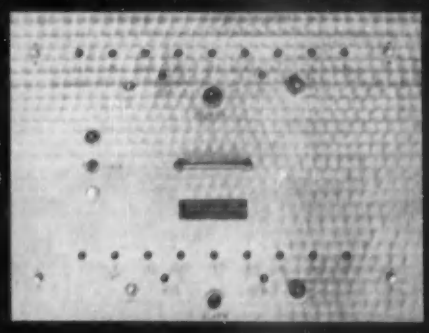
**THE GIST:** The system described in the preceding article ("Inspecting Missile Airfoils Automatically", p. 100) needs transducers that will measure within 0.0005 in. and present this positional information in binary-coded form. Conventional analog transducers are not accurate enough, and besides, their output would have to be converted to digital form before feeding the computer. But these requirements can be met by the Digamet, an optical digital position transducer using a binary-coded digital scale and a special reader. The transducer was conceived for direct position sensing on machine tools, inspection devices, and other equipment where position is the measured or controlled variable; however, it can be used to convert the output of any position-yielding primary transducer (such as force, pressure, acceleration, or thermal expansion) into digital form. The reading technique yields a unique coded signal for every position and permits minor imperfections in the edges of the scale lines and relatively large tolerances on skew without affecting reading accuracy. The scale used in this system is read while standing still. Dr. Kliever also describes high-speed circuitry for reading on the fly, which might be desirable for continuous contouring on machine tools.

Figure 1 shows a digital scale assembly and the control and auxiliary equipment panel used with the Convair Aerodynamic Surface Analyzer. First, the scale is driven into contact with the airfoil surface by a pneumatic cylinder. Then a unique binary-coded signal representing scale position is obtained by reading the zones in sequence, starting at the least significant binary digit (at the bottom of the scale) and working up to the most significant digit at the top. Neon lamps (two for each binary zone) are the light source, and light intensity is measured by a single photocell. Circuitry in the control panel selects the proper light source for each zone and delivers the binary-coded output signal

FIG. 1. THE SCALE AND ITS CONTROL



A. One of the scale assemblies for the Aerodynamic Surface Analyzer. The binary-coded scale moves in guides. The lamp-housing and the scale reader are in front of the scale, while the photodetector tube is at the rear.



B. Control panel and relay rack for system. Indicating lights show position of both stepping switches used to scan zones of the two scales. If desired, lights can be included that will indicate the binary-coded output of the transducers.

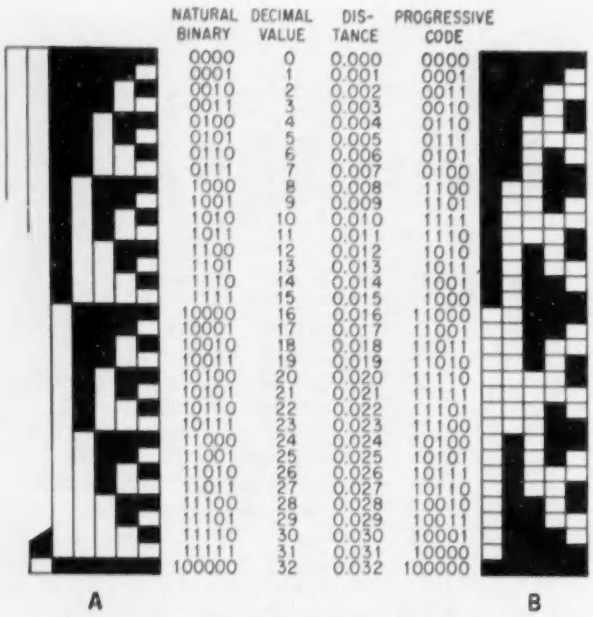



**FIG. 2. BINARY SCALES FOR MEASURING POSITION**

**A. Natural binary scale. Each position is unique, but more than one digit can change at one time, making cross-over equalization difficult.**

**B. Gray-coded scale. Only one digit changes at a time. One difficulty is in manipulating this code.**

in the form of a bank of open or closed relay contacts. The binary signal is fed directly to the surface-analyzer computer.

To perform as outlined above, the digital scale system must have the following characteristics:

- high resolution at high accuracy, including use of stable materials, like metal or glass
- ability to withstand millions of passes without loss of legibility due to wear
- unique output reading for each position, independent of previous operations
- output directly in natural binary or decimal numbers so that mathematical operations like addition and subtraction can be easily handled
- liberal mechanical and electrical tolerances in the manufacture and use of the transducer

## Digital scales

Before going into the reading techniques and logic of the system used here, consider some of the basic problems of digital position-sensing devices. Assuming that the scale intervals are divided to the desired resolution and accuracy, it is still necessary to identify each division. There are two basically different approaches to this.

For some applications it is sufficient to start at a known position and count the passing intervals, adding unit intervals for travel in one direction and subtracting for travel in the other direction. However, not only is it difficult to determine direction and make sure that counts are not lost at the turning points, but power interruption or spurious counts due to noise also introduce cumulative errors[1].

In contrast, individual fine divisions of a scale can be positively distinguished and identified by using additional "zones" on a scale, much as feet are used to identify the proper inch on a long ruler. In an "on-off" or binary system, the additional zones are divided into intervals, each coarser by one binary order of magnitude than the intervals in the previous zone. If the finest zone has divisions of 0.0005 in. opaque and 0.0005 in. transparent (for an optically read scale) representing binary zero and one respectively, then 16 zones will uniquely identify every 0.0005-in. interval for 32.768-in.

Figure 2A shows a multiple-zone scale in natural binary. Scales of this type are not new, but neither are they all alike. One of the principal points of difference concerns the exact timing of changes or cross-over of digits and the means for making sure that at the change from one number to the next, all of the digits change simultaneously. This is referred to as cross-over equalization. If the binary scale of Figure 2A is read with a simple slit and one photocell for each zone, ambiguities will exist at the points where several digits are supposed to change simultaneously. This occurrence can introduce large reading errors at cross-over, and is particularly troublesome in control systems that depend on rate information for stabilization.

Probably the best known method of preventing errors at cross-over depends on the use of one of the progressive or cyclic codes, such as the Gray

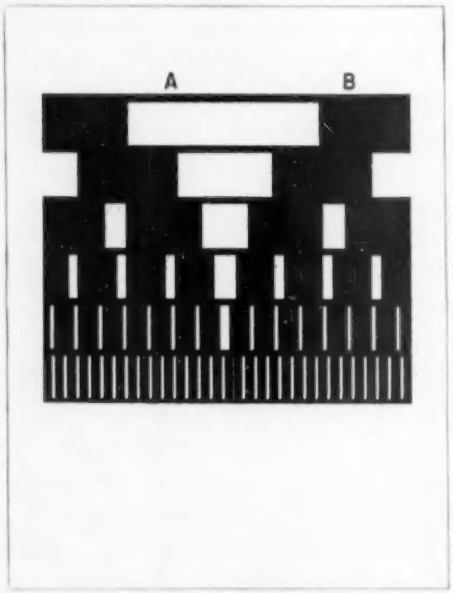



**FIG. 3. Digamet scale readers. Each zone or digit has two reading areas, A and B. Light intensity and switching program determine which side is read for each zone.**

code. This code bypasses the problem by shifting the binary zones so that only one of the digits changes at a time. Figure 2B shows a scale using the Gray code; it can be read with a single slit without fear of ambiguity.

To offset this advantage, the Gray code has several disadvantages. Cross-over of all zones, coarse or fine, must be as precise as the resolution required of the entire scale. On a high resolution scale, this places close restrictions on the permissible amount of skew and means that each individual line must be perfect. The latter problem can be minimized for the fine zones by using multiple slits, but little is gained since the coarse zones must cross over as accurately as the fine zones, and multiple slits are not practical in the coarse zones. A single slit also limits the amount of light transmitted.

Another disadvantage of the Gray code is that there is no convenient method to mathematically manipulate the code form. Therefore, Gray-coded numbers must be converted to the natural binary or decimal system before computation.

## The Digamet reader and logic

An alternative to the progressive codes uses natural binary scales with two readings per zone, one slightly advanced from the normal position of a single reader and the other similarly retarded. This technique uses a special form of reading head and a sequential switching program controlled from the so-called least significant (but actually most important) scale. The fine-zone readings select the appropriate reader for the successively higher-order digits. This method makes sure that all digits have correct values at the time of reading, even when the reading is very near a position where several digits need to change. These scales can be constructed in either linear or circular form.

Figure 3 shows an enlarged model of the reading plate. For each zone or digit there are two windows or reading areas, labeled A and B. These windows have opaque and transparent areas like those of the corresponding scale, Figure 2A, but are phased differently. In the actual scale there are two lamps or photocells per zone (one for the A side, one for the B side). Either the cells or the lamps can be switched to obtain the desired reading (the following method switches cells; the Convair model described later switches lamps).

Variations in light intensity as the scale moves past the reading head are shown in Figure 4. The switching circuit interprets the light densities of these areas as binary numbers, instantaneously representing the position of the scale. To achieve this result, the sections of scale in each reader window must be properly phased. Because it is easier and more accurate to compare measurements than it is to determine absolute values, the cross-over point for digits on the 0 (finest) zone was chosen as the point at which the readings of $A_0$ and $B_0$ are equal. Also, $A_0$ and $B_0$ are 90 deg out of phase. The contrast is better if they are 180 deg apart, however, with the 90 deg phasing it is possible to

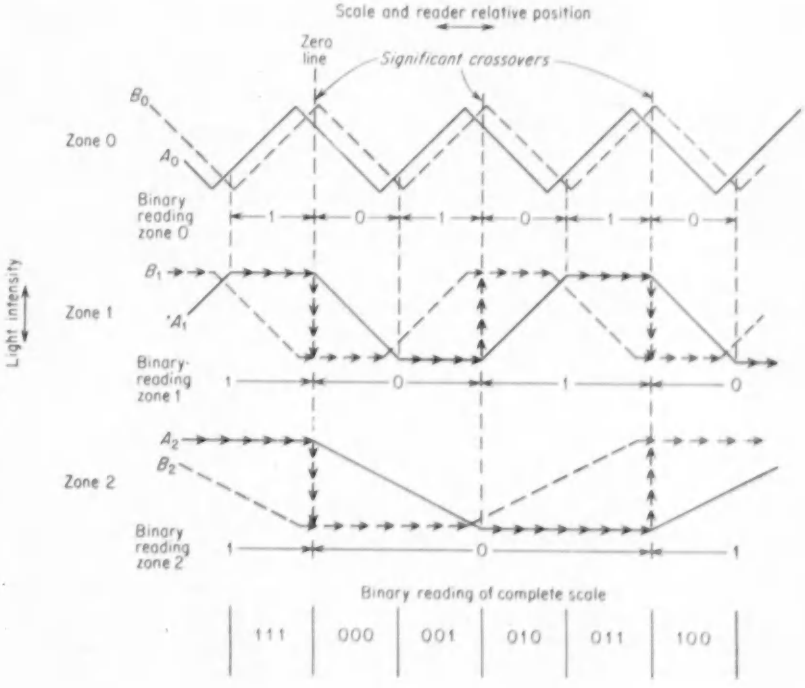



**FIG. 4. Variations in light intensity for three-zone scale as scale moves past reading head. The arrows on zones 1 and 2 indicate which side (A or B) is being read.**

interpolate to gain higher resolution than the distance between the 0-zone scale lines. Interpolation is covered later.

The phasing for scales 1 and higher is designed to provide good contrast at the points where zone 0 calls for a switch of zone windows. The phasing of all the zones can be better understood by referring to Figure 5, which shows one opening for each window on a greatly enlarged scale. In this figure, S is the center line for the reader zones beyond the 0 zone and is placed on a natural binary scale at the **0, 0, 0*** position. In this position, the reader is just at the change from **111** to **000**. Note that $A_0$ is 45 deg to the negative side or left and $B_0$ is 225 deg to the positive side or right, making them 90 deg (same as 270 deg) apart.

Zones beyond 0 are 45 deg of the particular scale to the right and left of the center line respectively. This and the fact that the apertures on the reader for all zones beyond 0 are one-half the width of the corresponding scale lines result in the flat-top waves shown for zones 1 and 2 in Figure 4, so the readings theoretically on zones 1 and higher are always all **0** or all **1**, and no readings with partial values need be identified.

Because of the 90 deg position of the two areas $A_0$ and $B_0$, their intensities yield alternate high-level and low-level points of equality. The high-intensity points of equality are selected as the "significant" cross-over points, calling for a change of digits in the 1 zone.

The logic for the 0 zone calls for two simple laws:

1. If $A_0$ is brighter than $B_0$, read **1**
   If $B_0$ is brighter than $A_0$, read **0**
2. If the 0 zone reads **1**, switch 1 zone to read $A_1$
   If the 0 zone reads **0**, switch 1 zone to read $B_1$

Following the above logic, the 1 zone has cross-overs at the same scale position as the 0 zone. All the higher-order zones have cross-overs not coincident with those of the next lower order.

While the selection of cell $A_1$ or cell $B_1$ of zone 1 depends on whether $A_0$ or $B_0$ is brighter, the selection of $A_2$ or $B_2$ does not depend on whether $A_1$ or $B_1$ was read, but only on whether the reading was bright or dark. In other words, it depends on whether the previous reading was **1** or **0**. Rule 2 above applies, and the logic for the entire scale can now be stated:

1. For zone 0
   If $A_0$ is brighter than $B_0$, read **1**
   If $B_0$ is brighter than $A_0$, read **0**
2. For any other zone
   Read *A* if the reading of the zone of next lower order is **1**
   Read *B* if the reading of the zone of next lower order is **0**
3. For the selected cell of any zone above 0 order
   If the light intensity is bright, read **1**
   If the light intensity is dark, read **0**

*Bold face numbers are in binary notation.

Figure 6 shows several typical reading positions of the enlarged demonstrator of the scale and reader. It is interesting to compare them with Figure 4.

As noted previously, the intensities are theoretically such that on all the zones except the 0 order, the cells read only true zeros and full ones, and never need to distinguish partial values. In practice, with a 0.0005-in. scale, a 2-mil spacing between scale and reading plate emulsions, and moderately parallel light beams, the lowest **1** is five times the value of the highest **0**. These features, together with the large apertures in the higher-order scales, make the readings highly independent of skew. Measurement depends on the fine scale, as it should, and the higher-order scales are essentially counters. On the whole, this system permits relatively large mechanical and electrical tolerances.

## Applying the scale

Scale materials are selected for permanance and durability, and must maintain the required dimensional stability despite age and changes in temperature and other environmental factors. It may be desirable to match the temperature coefficient of the scale with that of the workpiece rather than to take the usual approach of selecting the scale material for its low

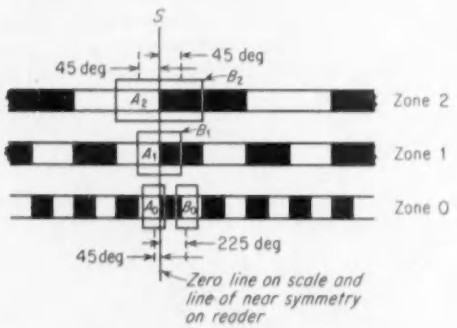



Table of values (move windows to right)

| ON ZONE 0 | | ON ZONE 1 | | ON ZONE 2 | |
|---|---|---|---|---|---|
| BRIGHTEST WINDOW | READ | SWITCH TO | READ | SWITCH TO | READ |
| $B_0$ | 0 | $B_1$ | 0 | $B_2$ | 0 |
| $A_0$ | 1 | $A_1$ | 0 | $B_2$ | 0 |
| $B_0$ | 0 | $B_1$ | 1 | $A_2$ | 0 |
| $A_0$ | 1 | $A_1$ | 1 | $A_2$ | 0 |
| $B_0$ | 0 | $B_1$ | 0 | $B_2$ | 1 |
| $A_0$ | 1 | $A_1$ | 0 | $B_2$ | 1 |
| $B_0$ | 0 | $B_1$ | 1 | $A_2$ | 1 |
| $A_0$ | 1 | $A_1$ | 1 | $A_2$ | 1 |
| $B_0$ | 0 | $B_1$ | 0 | $B_2$ | 0 |
| $A_0$ | 1 | $A_1$ | 0 | $B_2$ | 0 |

**FIG. 5. Expanded scale and reader with single line of windows, showing phasing for the various zones. The table demonstrates scale logic as the reader windows are moved to the right. For example, the first line shows that if $B_0$ is the brightest window, read 0 and switch to $B_1$. Then switch to $B_2$ and again read 0. Lines below apply as reader moves.**

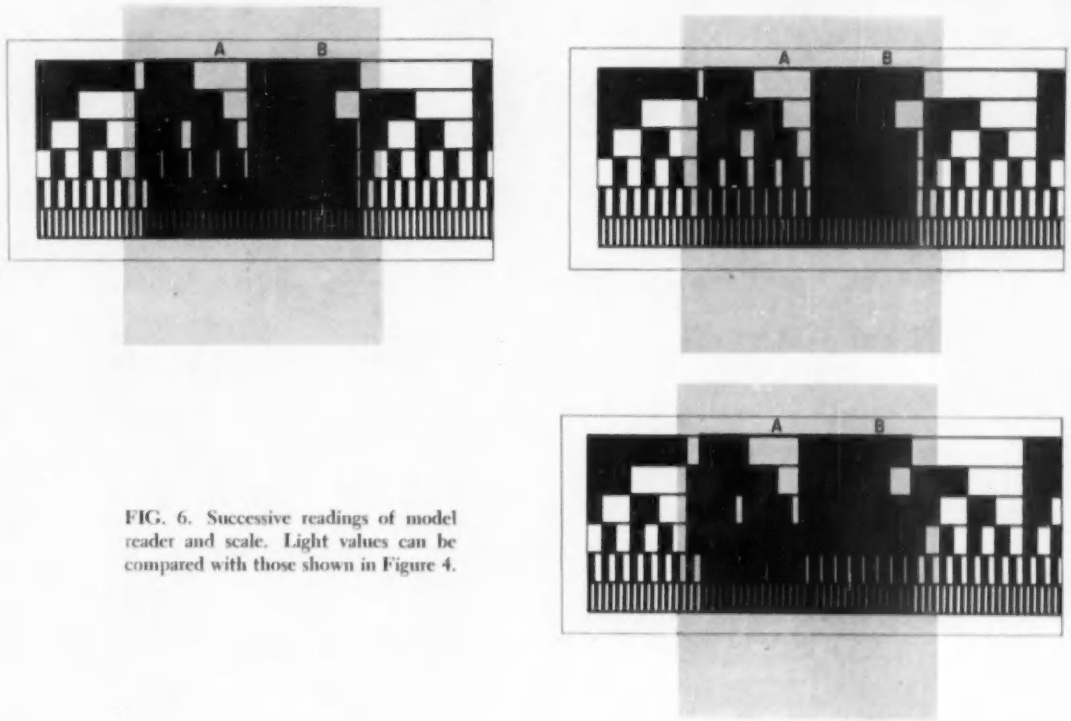



FIG. 6. Successive readings of model reader and scale. Light values can be compared with those shown in Figure 4.

temperature-coefficient properties. In this case, the workpiece and scale should be kept at approximately equal temperatures and also be clamped to the carriage at adjacent points. Inaccuracies introduced by differences in temperature or temperature coefficients can be computed from this common clamping point, and compensation can be introduced to prevent errors.

A glass scale (such is used in the Convair system) must be held without strain, yet prevented from moving in its reference frame. Reference contacts at the end are essential. The most difficult part of the mounting problem is maintaining a small constant space between the scale and the reading plate. Even when the light rays are collimated with lenses, the separation should be held to within 0.002 to 0.003 in. for a 0.0005-in. scale, or not over four to six times the minimum scale interval. Rather than depend on elaborate adjustments and on the precision of ways not manufactured by the scale supplier, it is more practical to support the reading head on an air film. This is described later.

Two types of applications require different kinds of circuitry:

*Stationary reading.* The scale is brought to the desired position, and the reading sequence, started manually or automatically, is performed while the scale is standing still. Here relay switching is practical.

*Reading while moving.* Unless the motions are quite slow, this calls for all-electronic circuitry including bistable elements. Readings are available sequentially, as required by many types of adding or subtracting computer circuitry. Or, if desired, the readings can be stored, either in the flip-flops associated with the scale or in buffer memories.

## The Convair-system scales

The Aerodynamic Surface Analyzer uses two 13-digit scales, each with a range of 4.096 in. A pneumatic cylinder on the transducer mounting drives a probe on the scale frame into contact with the airfoil. Readings are made while the scale is standing still. In this system, the zones and windows are switched by selecting lamps, and a single photocell senses light intensity. The reading head at the front of Figure 1A, which is mounted on reed hinges with spring pressure toward the scale, carries the reading plate and the lamp-house with 26 miniature lamps. It is adjusted so that the reader-plate surface and the face of the head are co-planar, and this plane is adjusted parallel with the scale. Air pressure at 15 psi maintains the space between the reader plate and the scale. The scale was manufactured by W. & L. E. Gurley Co.

Three safety devices prevent contact between the scale and the reader. The mating surfaces are coated with 1 mil of protective silicone varnish. Four pads 0.0005 in. high at the corners of the reader head outside the scale area provide the first contact if air pressure is lost. Then a spring-loaded bellows lifts the reader off the scale. The air maintains about 0.5 to 1 mil between varnish surfaces, or from 2.5 to 3 mils between scale and reader lines, permitting reasonable misalignment and keeping the system clean.

Figure 7 shows the optical system. Type NE-2 neon lamps are placed in position $L_1$ and $L_2$, and in $L_3$ and $L_4$ for alternate zones. This lamp arrange-

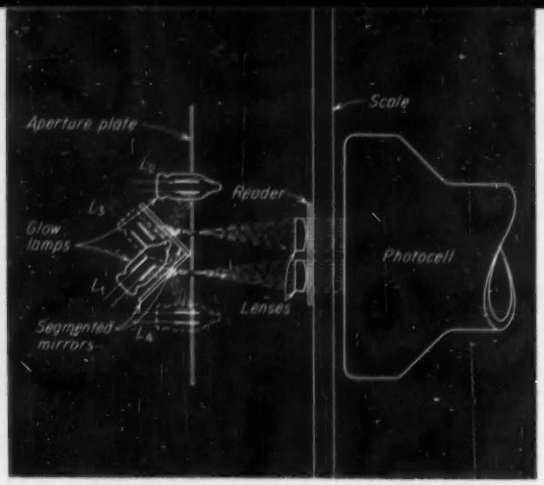



FIG. 7. Optical system for Convair scale. Lamp arrangement and segmented mirrors permit two individual light sources (for A and B sides) to be directed through each zone of scale.

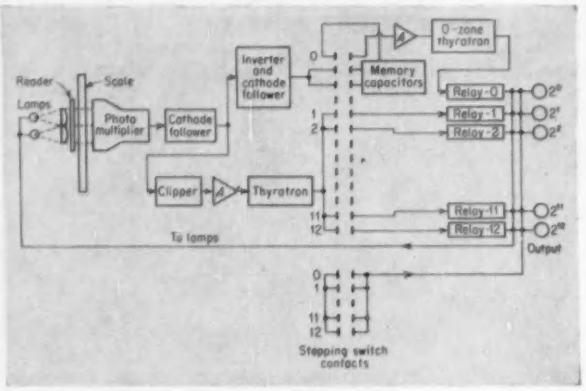



FIG. 8. Simplified block diagram of complete scale system. The stepping switch controls the reading cycle.

ment, together with segmented mirrors that have alternate strips of clear glass and mirrors of evaporated aluminum, allows individual illumination of the $\frac{1}{8}$-in.-spaced scales. On the three finest zones, lenses collimate the light to produce parallel rays through the scale and reader. This is not required on the coarse scales. The DuMont No. 6363 photomultiplier with an end-viewing cathode is large enough to intercept the light from all reader windows.

A simplified block diagram of the complete circuit is shown in Figure 8. The reading operation, controlled by the stepping switch which moves at a rate of 30 steps per second after receiving the read command pulse, proceeds as follows:

1. Lamp $A_0$ is flashed. The output of the cell and its associated circuitry charges memory capacitor 1 to a voltage depending on scale position.
2. Lamp $B_0$ is flashed; memory capacitor 2 is charged.
3. Memory capacitors are connected in series. If 1 has a larger charge, a thyratron pulls in the relay for zone 0, giving output of binary **1** and holding relay closed. If relay 0 is closed, lamp $A_1$ will be flashed in the next zone. (If $B_0$ is larger, relay 0 stays open, the output for the first digit is **0**, and $B_1$ is read in the next zone.)
4. Relay fires lamp $A_1$ or $B_1$, depending on the condition of relay 0, and sets relay 1. This yields either a **1** or **0** output and determines whether lamp $A_2$ or $B_2$ fires for the next zone.
5. Process continues until reading is completed.

## Interpolating the fine scale

This scale system can be read to a higher resolution than the width of a fine line, assuming the curves of $A_0$ and $B_0$ in Figure 4 are sufficiently well defined so that the information is available. This requires a good optical system with parallel light rays and a scale and reader closely spaced compared to line widths. A subdivision of four fits the binary system of the rest of the scale; with 0.0005-in. fine divisions (0.001-in. cycle) this represents resolution to 0.00012-in.

Since the $A_0$ and $B_0$ divisions on the fine reader scale are 90 deg of the scale cycle apart in phase, their readings change so that when the intensities of the cell readings are plotted on a phase diagram, the points define a square as shown in Figure 9. In practice the square tends to be rounded. The two readings at which the intensities of $A_0$ and $B_0$ are equal are the familiar switching points, one at a lower light level and the other at a higher light level. Choosing zero at the higher light level gives the advantage of greater sensitivity.

There are several techniques for identifying the eight points on the diagram. The vector $0P$ can be measured, and if means are available for determining $00'$, then the vector $0'P$ can be obtained by subtraction. The angle of $0'P$ identifies the point on the square.

## Error checking

Several techniques can be used so that the transducer system will check itself for false readings:

- parallel readings by two heads a fixed distance apart, and a continuous check of the difference
- counting of fine scale lines from a known or several known points, and adding or subtracting depending on direction to determine a position that can be compared automatically with the scale reading
- periodic return to known points to make check readings that are compared with known values. At least two readings are required to check all circuits, since only about one-half the windows are used for one reading
- a parity-type check can be made by adding a scale whose reading is **0** or **1** depending on whether the total number of ones in the correct scale reading is even or odd

Any of these devices can provide a warning or automatic shut-down if a discrepancy is indicated.

## Fast-reading circuitry

To read a moving scale, the circuitry must be fast enough so that readings of individual digits do not

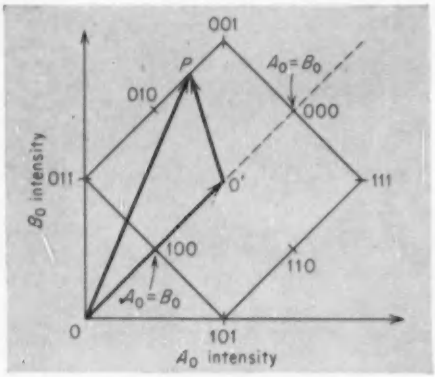



FIG. 9. Intensity phase diagram used in interpolating between fine scale divisions.

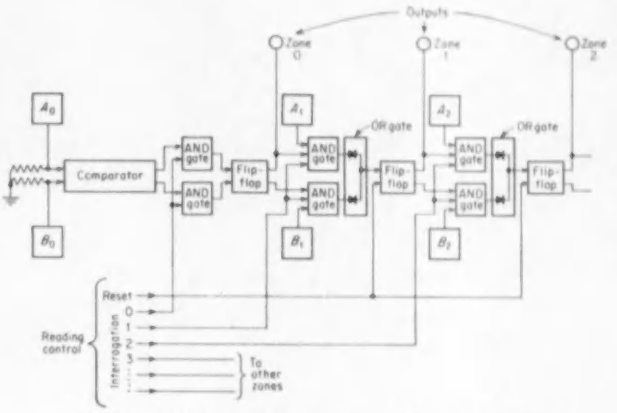



FIG. 10. All-electronic system for reading a scale on the move.

change greatly during the switching sequence. As an arbitrary standard, zone 1 must not move more than 15 deg of its cycle during the time between establishing the comparison of $A_0$ and $B_0$ and reading $A_1$ and $B_1$. For the scale discussed above, a 1-zone cycle equals 0.002 in., so that 15 deg is 0.002/24 in. With a reading of rate 48,000 pulses per second, the time interval from comparing $A_0$ and $B_0$ to reading $A_1$ and $B_1$ is 1/48,000 sec and the permissible rate of motion is (0.002/24)48,000 or 4 in. per second—approximately 250 in. per minute. Then 16 digits can be read in ⅓ millisec and the position determined is the correct one for the time when the reading sequence was started. During the reading, the scale would have moved a little over 0.001 in.

Fast electronic circuitry, such as shown in Figure 10, is necessary for reading under these conditions. This system will hold (store) any previous reading until a reset signal is applied. Then, on being interrogated by a reading control, it will read one digit at a time. The flip-flops can be any kind of bistable element, such as tube or transistor flip-flops, magamps with feedback, magnetic cores or others. The detectors, $A_0B_0$, $A_1B_1$, etc., are assumed to include amplifiers, which might be shared if both input and output are switched by the reading control.

A reading sequence of Figure 10 starts with a reset pulse that sets all the flip-flops for zones 1 and higher to **0**. Photodetectors $A_0$ and $B_0$ produce a voltage drop across the resistors to ground, and the comparator determines which voltage drop is larger and sends a voltage to the gate feeding the **1** or the **0** side of the first flip-flop. This voltage is only admitted when the reading control delivers the command "read zone 0". The flip-flop then applies a voltage at the 0-zone terminal if the **1** side is conducting; it applies no voltage if the **0** side is conducting. It also biases either the gate controlling the output of $A_1$ or the gate controlling $B_1$. On command to read zone 1, the biased gate permits either $A_1$ or $B_1$ to apply a voltage which changes the state of the 1-zone flip-flop to read **1** (or if no voltage comes from the zone read, the flip-flop is left in the **0** state). This process is repeated for the higher order zones.

In the AND gates, all inputs must be present if a voltage is to be delivered. Between the AND gates and the flip-flops of zones 1 and higher, diodes isolate the output of one detector from that of the other, forming an OR gate that will pass either one or the other of the input voltages.

The reading control may be one of the following:

► A fixed-frequency cycler, started by a suitable external read command signal. A self-cycling beam switching tube or a ring of flip-flops are possibilities.

► If all the flip-flops after the first one in Figure 10 are made monostable so that they return to **0** when no input is present, and if the interrogation input to the gates is removed, the circuit will recycle continuously if any zone is not satisfied.

► The reading signals may come from a control system in which the transducer is serving as a feedback element. For an example, consider the magnetic-tape-controlled system of Figure 11. The magnetic tape supplies numbers, interrogates the scale for actual numbers to be compared, and gates them simultaneously or sequentially to the computer as required. The difference, rate values, etc., are stored for the servo system to use until the next reading.

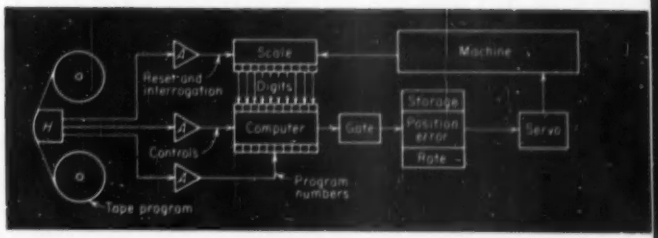
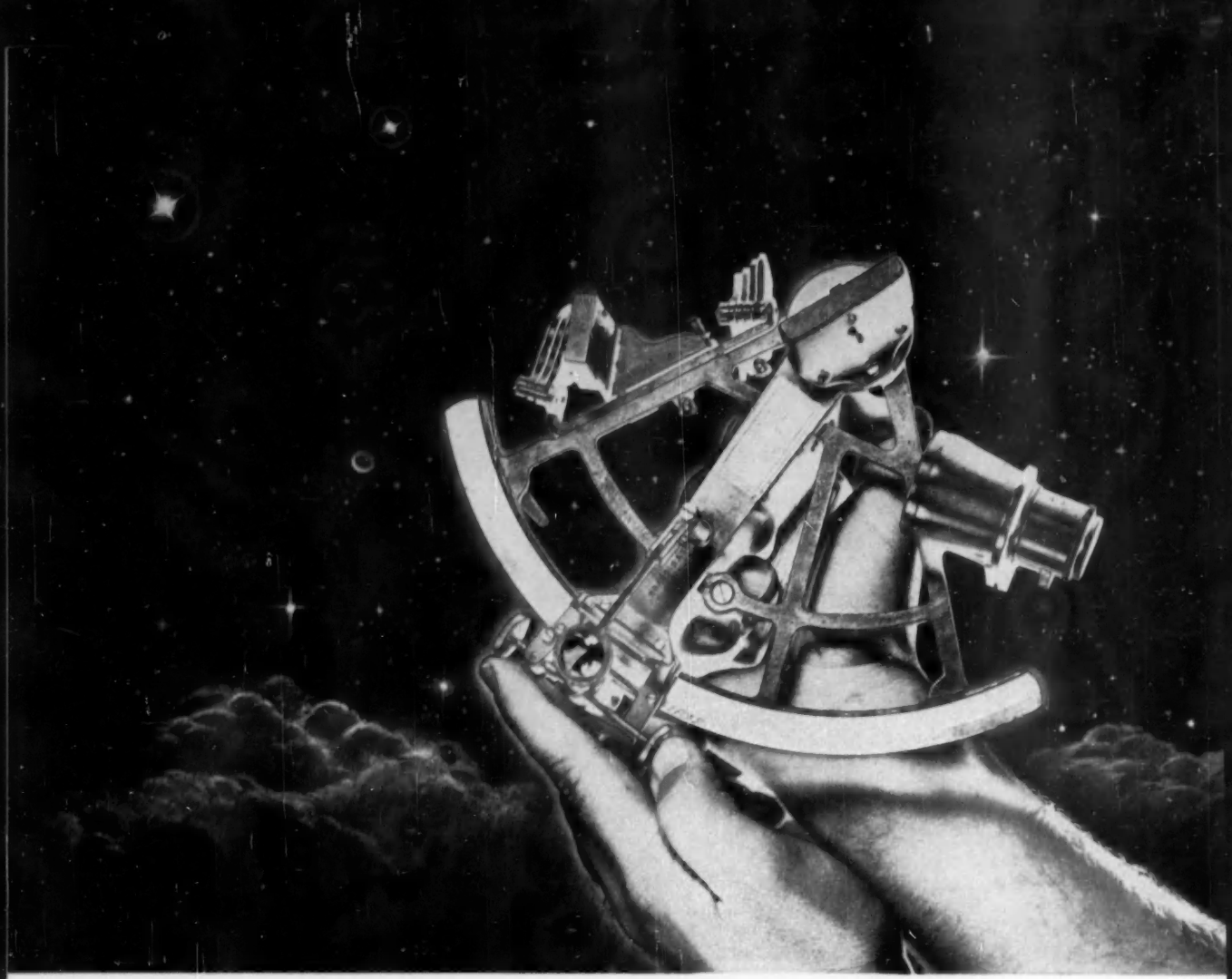



FIG. 11. Schematic of system with magnetic tape input and digital scale as positioning measuring element. A similar system might be used to program continuous-contouring machine tools.

## REFERENCE

1. *MEASURE MOTION TO 0.0001 IN.*, J. H. Brown, "Control Engineering", April 1955, pp. 50-52.



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# Input and Output Equipment

**The form of a digital computer's input and output equipment is dictated by the class of problems with which the computer is expected to deal. A general-purpose computer is best at handling "off-line" problems, such as scientific or payroll calculations. Such problems require flexibility in the input-output equipment, but usually not extreme speed. A digital computer intended to operate "on-line" as part of a control system is generally special-purpose, and its input and output equipment, though inflexible, may have to be very fast. The third class of problems considered are those which have to do with monitoring and checking the computer. These impose their own special requirements on the equipment.**

**MORRIS RUBINOFF, The Moore School of Electrical Engineering, U. of Pa., and RALPH H. BETER, Philco Corporation**

From the point of view of the input and output equipment, digital computers may be said to deal with three different classes of information. The type of problem to be solved, which distinguishes the three classes, also determines the kind of data with which the input and output equipment must operate.

Class I problems are those which can be completely specified in advance as far as the instruction program and the alphanumeric data are concerned. Such problems generally consist of direct calculations, such as payroll determinations, the generation of premium notices, calculations of stresses in physical structures, inversions of mathematical matrices, lens system designs, and the like. Class I problems are sometimes called "off-line".

Class II problems are those in which the digital computer is only part of a larger system that generates or determines data for the computer during the system's operation. Here the computer not only has the Class I initially-prepared data and instructions, but also accepts (and transmits) data from (and to) the other equipment in the system, under the control of its own stored program. Class II problems are generally those of control or simulation, such as industrial machine control, military fire control, navigation, cruise control, radar telemetering in real time, and the simulation of the responses of physical systems, as in flight training equipment. Class II

**Table I**

**CLASS I PROBLEMS**

| forms of input | forms of output |
|---|---|
| manual keyboard entries | printed sheets and strips |
| punched cards | punched cards |
| punched tapes | punched tapes |
| magnetized tapes | magnetized tapes |
| plug boards | plotted graphs |
| pin boards | |

EXAMPLES: off-line processing of information for use in business, research, statistics, engineering, and science, where all the data are supplied in advance.

**CLASS II PROBLEMS**

| forms of input | forms of output |
|---|---|
| analog quantities | analog quantities |
| electrical | electrical |
| mechanical | mechanical |
| temporal | temporal |
| others | others |
| digital information | digital information |
| (same as Class I input) | printed sheets and strips |
| | lights, annunciators |

EXAMPLES: on-line and controlling systems such as:

| | |
|---|---|
| industrial process control | military fire control |
| real-time simulation | navigation and cruise control |

**CLASS III PROBLEMS**

| input equipment | output equipment |
|---|---|
| switches | lights |
| pushbuttons | meters |
| keyboards | oscilloscopes |
| | audio amplifiers and speakers |

EXAMPLES: on-off control of the computer or its parts, stepping or recycling the computer, indicating the contents of specific computer registers, modifying the contents of specific computer registers, changing the logical functioning of the computer, indicating the general state of the computer's circuits

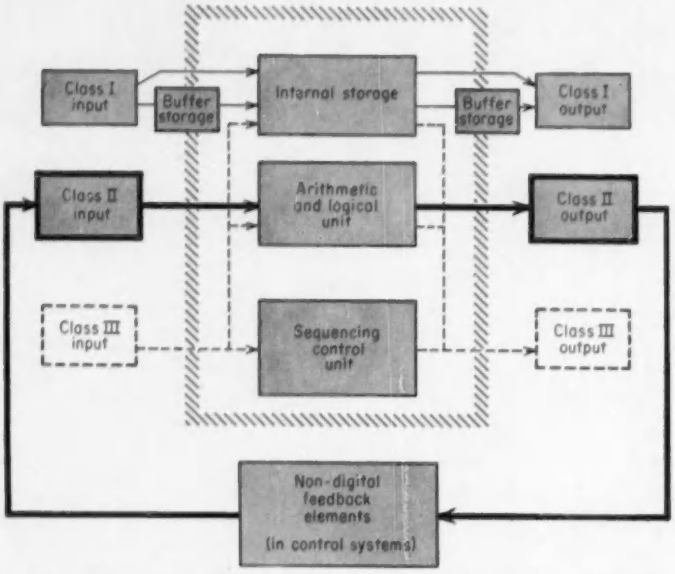



**FIG. 1. Flow of information between a digital computer and its environment.**

problems are sometimes called "on-line".

Class III problems are those which arise in monitoring the progress of a computation, manually testing operation, and maintaining or servicing a computer. Class III equipment generally consists of an operator's console and auxiliary apparatus furnished with a digital computer.

Class I information consists of alphanumeric data and programming instructions. Table I shows some of the ways that input and output data can be stored. If the output information is to be used in the computer later in the course of the same computation, then magnetic tape is the preferred output medium. Class I information is usually assembled and transferred to the computer in large blocks or quantities in advance of the associated data processing, and then transferred from the computer in large blocks after it is generated by the computations. The flow of Class I information through a digital computer or data processor is shown by the thin solid line elements at the top of Figure 1.

Class II input information is not known in advance, but is obtained from data generators which form part of the system. These data generators always handle quantitative data. Usually this information is generated as a proportional magnitude (analog quantity) and has to be converted into numeric (digital) form for the computer. Class II output information is generally required to be in analog form, so digital to analog conversion is also needed. In some systems Class II output information is used soon afterward as input information, completing a feedback loop through the analog portions of the system. However, in other systems Class II input information is under human control because the system loops are closed only by human agency; examples are a simulator used as a trainer, and an industrial control process monitored by a human operator. Class II data are usually transferred into the computer at uniform intervals as needed, and out of the computer at uniform intervals as processed. The flow of Class II information through a digital computer is shown by the heavy solid line elements in Figure 1; the feedback path is shown in block form at the bottom.

Class III input information is inserted through a keyboard or a bank of switches on a console which forms a part of most digital computers. These devices permit the entry of many types of information, such as alphanumeric data and instructions for modifying the computations or for testing the computer's operation. The switches may also enable the variation of power supply voltages or the interruption of computation at any point, such as after a group of instructions, after a single instruction, or after a step within an instruction has been performed. Class III output information, which covers the contents of any selected register in the computer and the functioning of the computer's circuits, may be presented in lights, on cathode ray tubes, on meters, in the form of typed messages, or even as audio signals.

The overall flow of information into and out of a computer may now be followed with reference to Figure 1. Class I information is recorded in advance on Class I input equipment such as tapes or cards, using a suitable keyboard device such as a typewriter or accounting machine modified for this process. The information is then transferred into the computer's internal storage medium, which is usually a high-speed variable memory. This transfer is made directly if the computer can transfer the information fast enough; otherwise some external storage medium may be used as a buffer. In a Class I problem the data entered into the internal memory are processed in the arithmetic and logical unit (ALU) in accordance with the stored instructions. The desired results are then transmitted from the memory to the Class I output equipment, either directly or through another buffer storage device.

In a Class II problem the instruction program is specified in advance together with prepared data, such as constants of the system and initial conditions for variables. Before the start of the computation, these are transferred to the internal memory, using Class I input devices. The Class II information, usually consisting of suitably digitally encoded shaft positions, voltages, time intervals, and other analog quantities, is sampled and transferred to the ALU whenever the instruction program specifies. The processing of Class II data involves comparing, combining, or interchanging with data stored in the computer's internal memory. Class II output data is usually transferred directly to the appropriate pieces of output equipment as soon as the data are ready.

Class II output devices usually regenerate analog quantities for use in the electrical or mechanical parts of the system with which the computer is integrated. These nondigital parts, which may consist of motors, electrical filter networks, a machine tool and its work piece, or a vehicle in motion, then feed back information to data generators which provide new data for the computer.

The Class II output data may also be transmitted to visual indicating equipment, such as voltmeters or dial indicators, to inform a human operator how the system is behaving or how he should participate in controlling the overall behavior of the system.

Table I summarizes the forms in which input and output information exist for the three classes of problems. The remainder of this article describes in detail the manner in which this information is handled and how it flows into and out of a digital computer. The three classes of problems will be discussed separately.

## CLASS I

### Off-line problems

As far as human interpretation is concerned, Class I information is essentially alphanumerical: that is, it includes all the symbols that may be found on a typewriter keyboard, together with any other symbols that may be used in the computer application, plus nontyping functions (such as space, tabulate, upper case, etc). Besides expressing numbers, words, and names, these symbols may be assembled in groups to represent other coded symbols, such as part numbers or computer instructions. As described earlier in this series of articles[1], the symbols are recorded in binary form, sometimes with extra binary digits that are useful in checking the recording of the information or its transmission to the computer. Also described earlier[2] was the way the computer may interpret transmitted information.

Class I input information is usually recorded on punched cards, punched tapes, or magnetic tapes, from which it is transferred to the internal memory of the computer either directly or through an external storage device or buffer. The buffer, if one is required, may be a magnetic drum, a photographic recording and reading system, or some other unit that can receive data slowly and deliver it rapidly.

A buffer is required if the computer's operating speed is decreased considerably when the computer must accept information during computation. This is particularly important if the computer does not have sufficient capacity in its internal storage to hold all the data and instructions for an entire problem. The buffer permits programming the computer to halt its problem-solving only occasionally and to accept substantial blocks of information in a relatively fast input transfer operation. With no buffer, the computer can accept only one or at most a few pieces of data at each call, either from its input device or from a register set by a human operator.

The design of some computers requires that input information be physically separated into program and data. For instance, in the Burroughs E101 computer the program is entered through a pinboard while the data are entered from an accounting machine keyboard. These two input devices may be seen in the photograph of the E101 computer, Figure 2. Pinboards, patch-cord wired panels, and other devices that store fixed information are Class I program-input or data-constant input devices, equivalent to a set of punched cards except that their information is used directly by the computer rather than transferred to another memory facility. Thus in this case fixed-information devices are part of the internal memory.

### Keyboards

Of the commonly used Class I input devices, the keyboard has the lowest information-handling rate. A human typist may achieve speeds up to ten characters per second for brief intervals, but average rates are considerably lower. Keyboards are therefore not used for direct entry of large amounts of information into a computer's internal memory unless the computer's time is not highly valuable. A keyboard-operated device might be used, however, to generate punched cards, punched tapes, or magnetic tapes, which are other commonly used Class I input devices. Information can be transmitted from punched cards or from punched tape at about the same rate; magnetic tape is much faster, provided that the tape is read out for long-enough times between tape starts and tape stops.

### Punched cards

Punched cards may be prepared by hand-operated key punches or by many types of automatic machines. The latter receive their information from magnetized tapes or strips, specially-marked papers, other punched cards, or the control equipment of the machines themselves. Card-punching machines operate at rates up to about 130 cards per minute. Card-reading machines can process up to about 250 cards per minute when transmitting information to a digital computer, and card-sorting machines can handle up to 800 cards per minute. Punched cards have up to 80 columns of 12 rows each.

Card-reading machines sense the holes by wire brush or pin contact through the holes. A faster card-reading method makes use of photocells which respond to light transmitted through the punched holes. Another rapid method for card-reading is based upon the decrease in the electrical capacitance between electrodes when a punched hole passes between them.

### Punched tapes

Paper tape may be punched by hand or by machine. Standard speeds for tape-punching machines are 6, 7½, and 10 characters per second. These speeds, standardized for commercial communications work, are not high enough in some instances. The Teletype Corp. has recently developed a unit that can punch 60 characters per second, and is currently designing one for 100 characters per second. The standard density of information on paper tape is ten characters per inch of tape length.

The usual method of tape reading involves pulling the tape into the reading position, and then advancing a row of pins up to the tape. Where the tape has been punched the sensing pins are able to move through the surface plane of the tape. Photoelectric readers are also available for punched tape. These readers do not require that the tape be stopped intermittently in order to read a character. A typical photoelectric reader, the Ferranti Mark IIA, will operate at a rate of 400 characters (40 in.) per second.

### Magnetic tapes

Tape speeds up to 8 ft per second are considered moderate for digital recording and reading on magnetic tape. Higher speeds are used for reeling and searching. Usable tape speeds are limited by mechanical considerations, such as the high accelerations and decelerations that must be provided if no recorded information is to be lost or skipped over.

**FIG. 2. Burroughs E101 computer has program instructions entered via the pinboard at right; problem data is entered via the keyboard.**

Binary digits are recorded on magnetic tape in parallel channels lengthwise along the tape, at densities of 60 to 700 binary digits per inch. The width of each channel is determined by the design of the recording head, and the interchannel spacing is determined by the overall width of the heads. Up to 14 channels per inch of tape width can be provided by heads mounted alongside each other in single stacks. The number of channels can be increased by staggering the heads of two or more stacks so that the channels interlace.

Relative skewing of recording and reading heads becomes a problem when wide multi-channel heads are used at high longitudinal recording densities. Sprocket pulses in one of the center channels may be used to mark a set of recorded pulses. Check pulses may also

be recorded in extra channels as a safeguard against pulses missed due to dirt on the tape or irregularities in the magnetic material. A typical manufacturer's specification allows errors due to tape flaws to occur no oftener than once in $10^9$ pulses.

Magnetic tape is superior to punched cards and tapes in that it can be erased easily and used repeatedly, and can be recorded much more densely. Its disadvantage is that it cannot be read visually, like punched cards and tapes; still, its information can be converted readily by machines into the punched or typed form.

#### Transmission links

If the source of information or its destination is remote from the computer, a wire or radio link may be used to transmit information. Wire links are more generally used, because of the problems of finding available frequency channels for the transmission of computer data by radio. If several sources of information exist for a computer, switching or time-sharing of inputs will be necessary. Outputs, too, may be switched or time-shared.

Any data that must be transmitted over significant distances for a Class I problem is likely to be digital. Either telegraph or telephone lines may be used for transmitting digital data. At present, almost 100,000 miles of lines are leased for computer services. Equipment is available for transmitting from five-channel punched tape to five-channel punched tape over telegraph lines at about seven characters per second, from punched cards to punched cards over voice lines at 15 characters per second, or from magnetic tape to magnetic tape over voice lines at 150 to 200 characters per second. Up to four independent card-to-card transmissions or up to 16 teletype transmissions can be made simultaneously over the same telephone line.

For future transmission of punched tape information, seven-channel tape has been proposed to replace the present standard five-channel teletype tape. Seven-channel tape permits many more different symbols to be coded, and allows for a parity check on the binary code digits for each symbol.

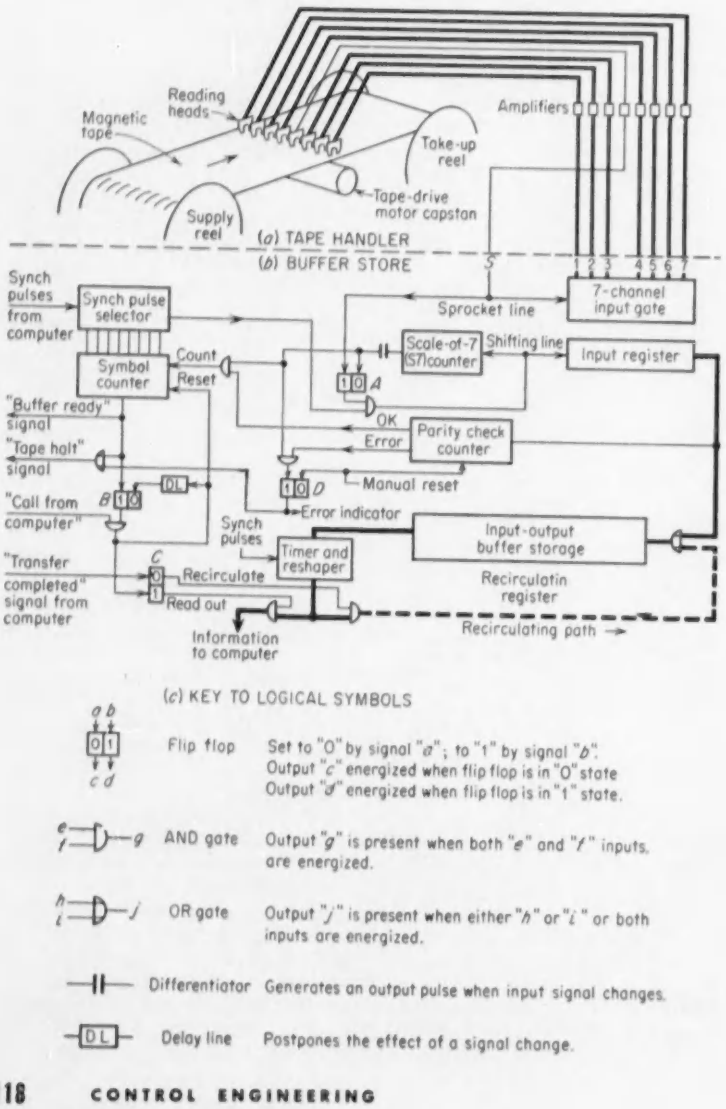
#### Output

Class I output information may be stored in the same way as Class I input information, except that pinboards or plugboards cannot be used. Class I output information may also be recorded as printed or graphed information, which cannot be used directly as input information later. Output information which is in the same form as input information, and which may be used later for re-entry into a digital computer, may be considered as semipermanent record material. Information in this form, either the program or the data to be processed, or both, may be treated as though it were in a temporary external storage medium, from which it can be transferred back into the computer. Output information prepared by alphanumeric printers and graph-plotters may be used for rapid-scan monitoring or for permanent record purposes.

The detailed flow of Class I information through a digital computer or data processor may be traced more easily for a typical system than for a general system. Figure 3 shows the logical equipment for transferring input information from a magnetic tape to a computer in such a typical system for a hypothetical serial synchronous computer. The symbols used in parts a and b of Figure 3 are identified in part c. The magnetic tape-reading heads and the reading head amplifiers shown in Figure 3a are parts of a tape-handling device. The tape-drive motor and its capstan, the reels for tape supply and take-up, and the necessary equipment for supplying power and control are only partially indicated.

The digital signal lines from this tape handler feed a buffer store. The buffer store, which may be packaged either separately or together with the computer, is here chosen to incorporate a serial recirculating register, which is most compatible with a serial computer. Several tape handlers may be connected to this same buffer store if some provision is made for transferring information from only one tape unit at a time. The buffer store register is shown in Figure 3b together with the necessary gating and control circuits.

FIG. 3. Typical input transfer of Class I information.




(c) KEY TO LOGICAL SYMBOLS

| | |
|---|---|
| Flip flop | Set to "0" by signal "a"; to "1" by signal "b". Output "c" energized when flip flop is in "0" state. Output "d" energized when flip flop is in "1" state. |
| AND gate | Output "g" is present when both "e" and "f" inputs are energized. |
| OR gate | Output "j" is present when either "h" or "i" or both inputs are energized. |
| Differentiator | Generates an output pulse when input signal changes. |
| Delay line | Postpones the effect of a signal change. |

The flow of information in Figure 3 is from the magnetic tape, through reading heads and amplifiers, through a gate system, into a buffer store input register, and from there to a recirculating register, where it is stored until it is transferred to the computer. This flow is shown in heavy lines.

The tape shown in Figure 3a has eight channels. Six of these channels are sufficient for coding all the alphanumeric, punctuation, and auxiliary symbols. Another channel may be used to carry parity digits for checking the reading accuracy. One of the channels nearest the center of the tape is the sprocket channel, which always has a binary one whenever a coded symbol has been recorded in the other seven channels. In this hypothetical system the parity digit accompanies its symbol-code digits everywhere except in the arithmetic and logical unit. In the latter, parity digits are stripped off incoming information and have to be reassigned to output information.

When the tape is moved past the set of heads in Figure 3a, the heads generate signals that pass through the amplifiers where they are amplified and shaped. From the outputs of the amplifiers in the tape handler these signals go to a set of parallel gates in the buffer store. The seven signals that carry the symbol code and its check bit are gated to the input register whenever a sprocket pulse appears. This input register receives the seven bits in parallel, and delivers them sequentially (serially) in the proper order at a later time. The input register therefore serves also as a parallel to serial converter. The conversion is accomplished by making the input register a shifting register that transfers each stored bit to the right whenever a shifting pulse is received.

From the last binary storage element in the converter each stored bit is transferred to the output line. Seven shifting pulses are required to transfer the seven stored bits in sequence. As this output transfer is taking place at one end of the shifting register, binary zeros shift into the register at the other end, so that after the seven bits have been shifted out, the input register is left "cleared" and ready to accept the next seven bits of information. The proper time for shifting out of the input register is when the code digits for a symbol can be placed in the recirculating register directly behind the previously-recorded symbols. Until this time, the shifting line to the input register is not supplied with pulses. The control of the shifting pulses will be discussed later.

The recirculating register chosen for the buffer storage is one whose serial information rate must be identical to the rate in the computer. This feature

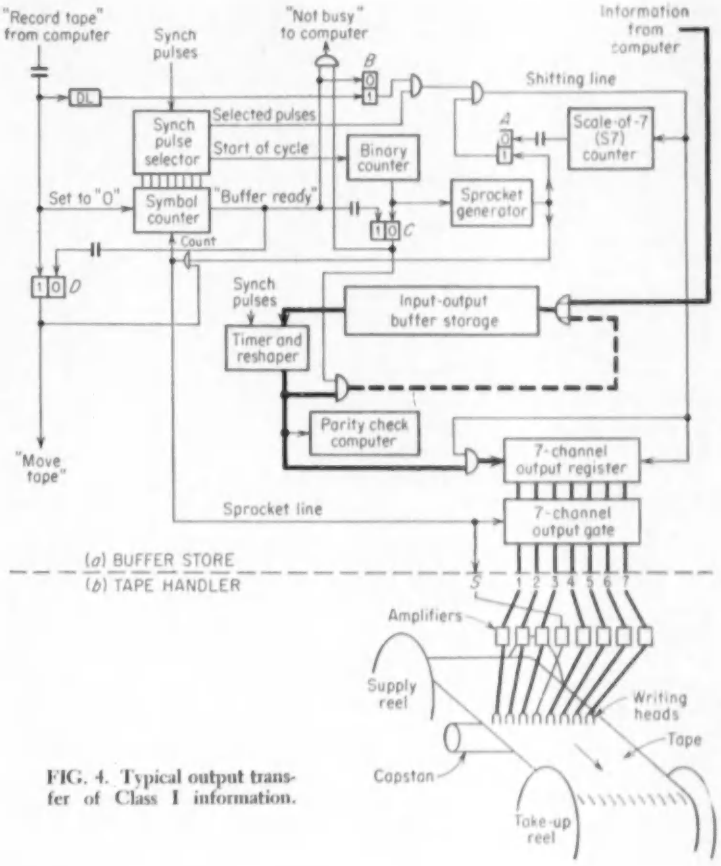



**FIG. 4. Typical output transfer of Class I information.**

simplifies the problem of pulse timing during transfers between the buffer store and the computer's internal memory. The information rate in the buffer register is determined by synchronizing pulses that come from the computer. The symbol digits that enter the buffer register are timed by shift pulses which are selected from these synch pulses. After the information pulses have gone through the main delay element labeled "Input-Output Buffer Storage" in the recirculating register, they are again timed by the synch pulses. Because the storage element, which furnishes most of the delay in the register, degrades the information pulses, the emergent pulses usually need to be reshaped as well as retimed. The information in the buffer register must be retained by continuous circulation until it is to be transferred to the computer. The recirculation path therefore normally permits the reshaped pulses from the delay element to re-enter the delay element.

Control of the input information flow is handled mostly by the control circuits in the buffer store, Figure 3b. These circuits communicate with the tape handler and the computer, as well as with the buffer store circuits. The control circuits associated with the error indicator communicate with the human operator.

Transfer of information from the tape handler to the buffer store recirculating register is controlled by the symbol counter, the synch pulse selector, and the scale-of-seven counter. These three component circuits are linked with the parity check counter and the error indicator, both of which will be discussed later. Each sprocket pulse that enters the buffer store starts an operating sequence that gates the corresponding code digits into the input register, stores them there as long as necessary, and then shifts them out into their proper locations in the recirculating register. The symbol counter advances by one count at the completion of each such sequence.

The instantaneous count that exists in the symbol counter is continuously transmitted by parallel lines to the synch pulse selector. This selector is a network that performs several functions. It counts the synch pulses over and over again in such a way as to always indicate which coded-symbol location in the buffer store register is available for loading or unloading. The selector compares this location number

with the number in the symbol counter: when these numbers coincide, a train of seven synch pulses is gated out of the selector. A seven-pulse train therefore appears at the selector output once during each recirculation time of the buffer store register. The scale-of-seven (S7) counter limits the buffer store input register to only seven of these selected synch pulses for each symbol that must be shifted out.

When the buffer store is ready to accept a new symbol, the S7 counter rests on zero, after having set flip-flop A to the "0" state. The sprocket pulse for the next symbol sets flip-flop A to "1", which energizes a gate that controls the passage of the selected seven-pulse trains to the shifting line. If the sprocket pulse sets flip-flop A to "1" in the time interval between the seven-pulse trains, the input register will be unloaded by the next seven-pulse train. This will take place within one recirculation time of the buffer store register. If the sprocket pulse arrives at flip-flop A between the start and the end of a seven-pulse train, the later pulses in that train will transfer some of the code digits out of the input register within one recirculation time, and the rest of the code digits will be unloaded into their proper locations in the buffer store register by the initial pulses of the pulse train that occurs one recirculation time later.

Regardless of whether the transfer from the input register takes place within one recirculation time or two, the S7 counter permits only seven pulses to actuate the shifting circuits of the input register. The seventh shift pulse returns the S7 counter to the "0" state. When the S7 counter triggers to zero, it sets flip-flop A back to "0", and it also advances the symbol counter by one count. Since the S7 counter in the "0" state generates a signal that would lock flip-flop A in its "0" state indefinitely, only the change of state of the counter is permitted to reach the flip-flop. This is accomplished by including the differentiator in the output line of the counter. This differentiator passes a pulse only when the S7 counter changes its state back to zero.

The circuits and the operation described so far could work satisfactorily provided that the symbols coming from the tape handler arrived with a time-separation of at least two buffer-register recirculation times.

As soon as the number of symbols in the buffer storage register is equal to the designed capacity of that register, the symbol counter will generate a "buffer ready" signal, which is transmitted to the computer to advise it that it may transfer the buffer store contents to its internal memory whenever convenient. The "buffer ready" signal will also be transmitted back to the tape handler through an OR gate to stop the movement of the tape. This "tape halt" signal makes sure that symbols will not be read from the tape when they cannot be accepted by the buffer store. Termination of this "tape halt" signal will be discussed later.

The "buffer ready" signal sets flip-flop B to the "1" state, which opens a gate for the "call from computer" signal. The latter is sent out by the computer when it chooses to respond to the "buffer ready" signal. When the "call from the computer" signal arrives, it sets flip-flop C to the "1" state.

Before flip-flop C was triggered by this signal, it was in the "0" state, holding open the recirculation gate in the buffer storage register. In the "1" state, flip-flop C prevents passage of the serial contents of the register through the recirculation gate, and permits the contents to be read out to the computer instead. After the buffer storage contents have all been transferred to the computer, the computer transmits a "transfer completed" signal to the buffer store, to reset flip-flop C to the "0" state. The readout of the buffer store register takes place in exactly one recirculation time of the buffer store register, but this register is able to accept new symbols as soon as the readout commences. This is true because holding the recirculation gate closed clears out the old contents of the register in serial fashion. It is therefore safe to reset the symbol counter with the "call from computer" signal. This reset signal can be terminated by passing it through a delay line and then using it to set flip-flop B back into the "0" condition. As soon as the symbol counter is reset, it can no longer generate the "buffer ready" and "tape halt" signals, so the tape drive motor can resume moving the tape. The counter then starts counting stored symbols all over again.

#### Tape searching

The computer may have to specify the location of the next block of information which it seeks from the tape if this specified block is elsewhere on the tape than directly following the block just read. This implies (1) that there is communication directly from the computer to the tape-handling device, (2) that pulses from the tape are prevented from actuating any of the buffer store circuits during tape search, and (3) that equipment is provided for keeping track of the location of information on the tape. The equipment for computer-controlled block-searching is not included in Figure 3.

The OR gate that emits the "tape halt" signal was mentioned above in connection with the "buffer ready" signal. This gate is energized when an error is detected by the parity check counter, as well as when the buffer store is full. The parity check counter shown in Figure 3b is simply a binary (modulo 2) counter which is triggered by every binary one that is shifted out of the input register. This counter has two outputs, "OK" and "error". If the counter has been triggered by an even number of binary ones from the seven code bits shifted out of the input register, the "OK" output line from the counter will be energized in time to gate the differentiated signal from the S7 counter into the symbol counter. However, if the parity check counter stopped on an odd count when the shift-out from the input register was completed, the "OK" signal would be replaced by the "error" signal. This "error" signal gates the differentiated pulse from the S7 counter into flip-flop D, setting the error indicator flip-flop to the "1" state. In this state, the flip-flop generates the "error indicator" signal, which may turn on an error light as well as give rise to the "tape halt" signal.

The occurrence of an error detectable by the parity check counter stops the tape-reading operation and presents an indication to the human operator. Whatever the human operator chooses to do in response to this error indication involves Class III equipment, which is not the topic of the present discussion. However, Figure 3b shows a "manual reset" signal line which can be energized by the operator after he has completed the necessary corrective procedures. This "manual reset" signal restores both the parity check counter and the error indicator flip-flop to the "0" state, thereby permitting the equipment of Figure 3 to resume normal operation.

The input system just described requires immediate human intervention when an error is detected. Much of this intervention can be made automatic, although some human intervention will always be needed. For instance, the input circuitry could be arranged to move the tape backwards and forwards one or more times in an automatically-controlled attempt to re-read the information for which the error was registered initially. Errors due to the presence of foreign particles between the tape and the reading heads, are cleared up by this method. Alternatively, more elaborate coding methods than the simple error-detecting parity code could be employed, such as an error-correcting code.

#### Output control

The flow of Class I information out of a computer may be handled by the

logical equipment shown in Figure 4. This equipment, consisting of a buffer store and a tape handler, accepts blocks of information from the computer and records them on magnetic tape. The equipment of Figure 4 is compatible with the computer system postulated for Figure 3. The logical symbols used in parts a and b of Figure 4 have been identified in Figure 3c.

Many of the component circuits shown in Figure 4 are identical in design and operation to the component circuits of Figure 3; in fact, the logical equipments shown separately for the input and the output functions may be coalesced readily. Thus, only one buffer store and only one tape reader may be implied in Figures 3 and 4 combined. The following discussion, however, will be limited to Figure 4.

The heavy lines in Figure 4 show the information flow from the computer's internal memory to the buffer store recirculating register, from which it is read out, one symbol at a time, into a seven-channel output register. At intervals a seven-channel output gate in the buffer store transmits the symbol code bits simultaneously with each other and with a sprocket pulse. This information is transmitted to writing head amplifiers in the tape-handling device. These amplifiers generate the signals used by the writing heads for recording each symbol and its sprocket on the tape.

More than one tape handler may be used with the buffer store of Figure 4a. Circuits would then be required that could effect the selection of one of these tape handlers at a time. These circuits are not in the figure.

The operation of the control circuits shown in Figure 4a may be explained briefly by assuming that the buffer store initially is transferring its contents to a tape, that it is then filled by the computer, and that it again resumes its transfer of contents to tape.

The symbol counter keeps track of the symbols transmitted from the buffer store to the tape. These symbols are gated and shifted into the output register by selected pulses that appear on the shifting line. Each symbol is transferred to the tape by a sprocket pulse, which also steps the symbol counter and opens the gate for the next selected pulses.

When the last symbol has been read out, the symbol counter will have counted up to its capacity and will generate the "buffer ready" signal. The initiation of this signal sets flip-flop C into the state that causes the recirculation register to be cleared. This signal also reaches flip-flop B, maintaining it in the state that causes a gate to block the seven-pulse trains, and it resets flip-flop D, stopping the tape.

Recirculation of the buffer store register starts with the next "start of cycle" pulse that gets through the binary counter and resets flip-flop C. No more "start of cycle" pulses are generated until the next tape-recording operation takes place.

During transfer-to-tape operation and while the recirculating register is being cleared, the computer should not try to load the buffer store; therefore a "not busy" signal is provided in Figure 4 to inform the computer when loading may take place. The computer can load the buffer store at any time without affecting the control circuits in the buffer store. The computer determines how many symbols (up to the store's capacity) shall be loaded, and how the symbols shall be placed relative to each other in the buffer store. When the loading job is finished, a "record tape" signal from the computer unlocks or activates all the buffer store circuits that control the transfer-to-tape function.

The input and output equipment just discussed is one of many equally good designs. Other designs may incorporate different features, involve other timing and sequencing, etc. Although the details of the equipment may change from design to design, and although the design may change from system to system, the basic functions of information gathering, transferring, storing, and clearing will always be involved. As will be seen, these functions must be provided in Class II equipment as well as in Class I.

## CLASS II
### On-line applications

The data variables in a Class II problem consist mostly of quantities that change continuously outside the computer; thus, from the standpoint of input and output equipment, a computer for a Class II problem is characterized chiefly by the emphasis that has been placed on rapid transferral of data between the outside and the computer's arithmetic unit. Furthermore, the facilities for transferring information to or from the internal memory may be somewhat deemphasized or modified.

Class II data will be in analog form while being handled or generated in the physical equipment outside the computer, but must be in digital form while it is in the computer. Suitable ways to express this data, in both the analog and digital forms, are listed in Table II. The transmission of data between the physical apparatus and the computer almost always is accomplished intermittently, with attendant problems of accuracy, precision, sampling time, smoothness, and lag. The transmission itself may be by direct linkage, in either the analog or digital form, or by radio or wire links, as modulated or coded electrical signals.

The process of converting data from one form to another may involve several steps. A temperature reading, for instance, may be obtained indirectly in the form of a direct current voltage, which is first amplified and then encoded. Of the forms of analog quantities listed in Table II, the mechanical, temporal, and electrical may be converted more readily than the others into a digital form. Mechanical quantities, for instance, may be encoded by any one of several commercially-available shaft-position-to-digital converters. These converters may be obtained with digital output in binary, progressive

**Table II a) ANALOG FORMS OF CLASS II INFORMATION**

| | | | |
|---|---|---|---|
| **electrical** | | (voltage or current) | |
| **thermal** | | | |
| **optical** | | | |
| **acoustical** | **direct current** | **sinusoidal waves** | **pulses** |
| **temporal** | —amplitude | —amplitude | —height |
| **thermal** | —polarity | —phase | —width |
| **chemical** | —rate of change | —frequency | —rep. rate |
| **hydraulic** | | | —duty cycle |
| **pneumatic** | | | |
| **mechanical** | | (rotation or translation) | |
| | | —position | |
| | | —speed | |
| | | —acceleration | |

**b) DIGITAL FORMS OF CLASS II INFORMATION**

**Signed magnitude** or **complement**

**parallel** or **serial**

—most significant digit first

—least significant digit first

binary[8], decimal, or binary-coded decimal code. Of the devices available for electrical analog to digital conversion, those with voltage inputs have been furtherest developed. Temporal quantities may be encoded by counting methods, using pulses or voltages at a predetermined fixed frequency. The devices and techniques used in conversion will be discussed in the next article of this series. The problems of conversion accuracy, precision, sampling time, data-smoothing, and data-lag have been discussed by R. M. Leger and J. L. Greenstein in "Simulate Digitally or by Combining Analog and Digital Facilities", CONTROL ENGINEERING, September 1956, page 145.

Figure 5 shows a typical arrangement of Class II input and output devices, with their associated equipment. The information flow, indicated by heavy arrows, is clockwise in the figure, circulating between the analog equipment on the left and a parallel binary computer on the right. Input quantities 1 and 2 and output quantities 4 and 5 are mechanical shaft positions of ten-, seven-, eight-, and five-bit precision, respectively. Each of these quantities is converted into a special code that must be translated for the digital computer. The converters associated with quantities 4 and 5 are parts of digital feedback loops which will be discussed later. Input 3 turns a switch on or off; thus it may be treated as an analog quantity with a precision of only one bit. No translation is required for quantity 3 because it can be encoded directly into the binary number system used by the digital computer. Output 6 is an electric current that can be indicated by a meter or used by other kinds of analog equipment.

There are two reasons for using digital feedback in generating quantities 4 and 5. For quantity 4, feedback permits a quantity of eight-bit precision to be derived from a quantizer of only five-bit precision. In both cases, the output shafts are turned by servomotors (SM) which respond to signals determined by the digital computer. Because a servomotor integrates its input signal, this signal must supply only the changes—that is, the "error"—in the output.

The "amplify and hold" blocks in Figure 5 indicate the circuits that amplify the quantizer output voltage for each channel, and that hold or store this voltage when the quantizer is idle or supplying other channels. The holding circuit element functions primarily as a low-pass filter, although it has some of the properties of an integrator. In channels 4 and 5 each amplified and stored voltage modulates the ac applied to the corresponding SM control winding.

### CLASS III
### Computer checking problems

All the communication between a digital computer and the world outside it involves input and output equipment or facilities. That information and equipment which is commonly referred to as "input" and "output" has been discussed under Class I and Class II. All the computer communication that is not included in these categories is in Class III.

### CLASS III

Class III information is communicated through the control, monitoring, and servicing facilities of a digital computer. These facilities may involve or affect any part of the computer and its auxiliary equipment. Class III equipment used in control and monitoring is arranged for the convenience of the computer's operator, and the equipment useful in servicing is arranged for the convenience of maintenance personnel.

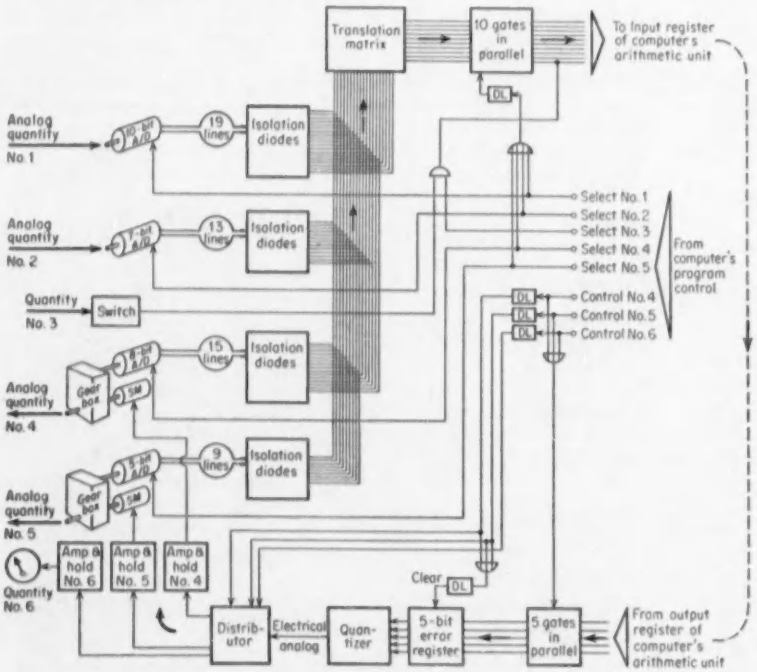
Rotary or toggle switches, pushbuttons or other electrical contact devices, or plug jacks may be used to enter Class III information into a computer. Information to be entered includes: off-on control, commands for stepping, continuous running, clearing, and resetting; options concerning program branching; choices between various input or output media or channels; and variations in circuit supply voltages.

Indication of computer operation can be obtained from lights, cathode-ray tubes, meters, typing devices, or audio amplifiers. The contents of one or more registers in the memory, control, or arithmetic portions of the computer may be displayed in a pattern of lights or may be typed out; this information is useful in monitoring the progress of a computation. Program monitoring may be accomplished by plotting, on a cathode-ray tube, the pattern formed by the successive memory addresses consulted while the computation is in progress. The presence of an error or of an overflow of data may be indicated by a light or by an audible alarm. The functioning of the computer circuits themselves may be indicated on meters or by cathode-ray-tube patterns.

Figure 6 shows a control panel layout that includes many of the features just mentioned. The center section of this panel has been made wide enough to display the contents of all the 36-bit registers. Various lights, switches, and meters, together with a small cathode-ray tube, have been arranged on the two flanking sections.

The top row of the left-hand section has a power on-off switch and a pilot light. It also has an indicator light that shows when the computer temperature is outside the design limits, and three horizontal strips of lights that indicate the code for each five- or seven-bit symbol entering or leaving the com-

FIG. 5. Typical Class II input and output.



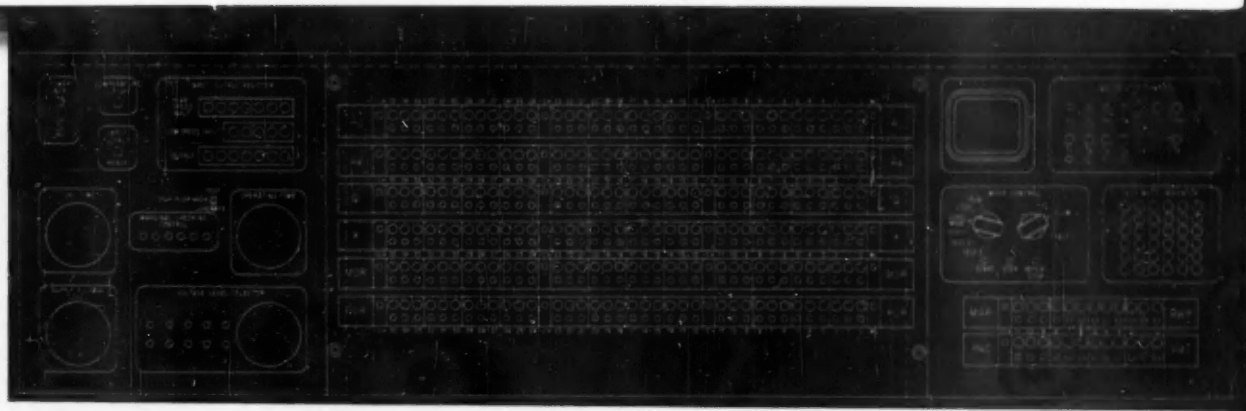


FIG. 6. A control console for Class III input and output.

puter. The middle row has two elapsed time meters, one for "on" time and one for operating time. It also has a set of lights used in marginal checking of the circuits, and a three-position toggle switch. This switch can be used to insert a string of binary ones into every register, or to turn on every register-indicator light without affecting the registers. The bottom row has two meters, one for the supply voltage and one, with pushbuttons, for checking computer circuit supply voltages.

The center section of the panel of Figure 6 has six 36-bit rows, one for each of the four arithmetic registers ($A_L$, $A_R$, Q, and X), one for the memory data register (MDR), and one for the program control register (PCR). Each register can be cleared all at once (master clear, MC) or 12 bits can be cleared at one time (clear, C), by pushing the appropriate button. Once a register or a part of it has been cleared, it can be loaded with binary ones by pushing the buttons under the appropriate lights. Each light is on when the corresponding part of the register holds a binary one.

The top row of the right-hand section has a small cathode-ray tube for monitoring the memory-address communication pattern. Each time the memory is consulted, a spot on the tube is illuminated at a location corresponding to the x- and y-coordinates of the address. The rest of the top row has a set of switches and lights used for program branching—"jump or stop control". The middle row has selector switches, pushbuttons, and lights for selecting modes of operation of the computer, including several test modes. The bottom two rows of this right-hand section have the same arrangement of lights and pushbuttons as the middle section; these rows are used for the two 12-bit registers, the memory address register (MAR), and the program address counter (PAC).

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**RALPH H. BETER**

Mr. Beter, now a project engineer in Philco Corp.'s Control Systems Group, joined the company in 1953 to help establish the Digital Computer Section. Later he participated in development of Philco's TRANSAC series of digital computers. He holds a BEE and MS from Marquette, where he taught physics for five years. He also has been with Eckert-Mauchly Div. of Remington-Rand, Electronic Computer Corp., and Arma Corp.

**MORRIS RUBINOFF**

Dr. Rubinoff managed to crowd in work for a BA, MA, and PhD at Toronto Universiy in the five years between 1941 and 1946, when he was also active in the war as a member of the Canadian National Research Council. He joined University of Pennsylvania's Moore School of Electrical Engineering in 1950 after some time at Harvard (fellow in applied science, instructor in physics) and Princeton's Institute of Advanced Studies.


**This magnetic amplifier control acts to permit mixture of two liquids only when they are nearly the same temperature, regardless of what that temperature is, within the range from 50 to 650 deg F.**

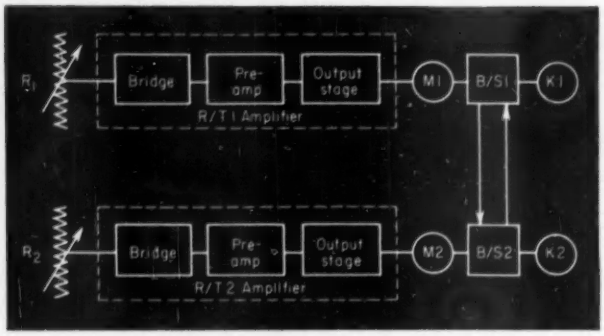



FIG. 1. Temperature difference detecting system.

# Control by Temperature Difference

**W. M. KENDZIOREK**
**Westinghouse Electric Corp.**

Magnetic amplifiers are being used in more and more applications requiring the utmost in reliability and continuity of service. In one such application, two liquids must be prevented from mixing with each other unless their temperatures are very nearly alike. The valves controlling the flow of the two liquids are actuated by a magnetic amplifier system that measures the temperature of the two liquids and senses the difference between them. When the difference becomes less than some predetermined magnitude, the valves are permitted to open and the liquids may intermix.

Such a system was actually constructed for an application where the two temperatures in question ranged from 50 to 650 deg F and where the difference to be detected was adjustable from 25 to 75 deg F. The system trips a relay whenever the prescribed temperature difference is reached, regardless of the actual value of the two temperatures in their range.

The system maintained an accuracy of better than 2 percent for variations of plus or minus 10 percent in line voltage, plus or minus 5 percent in power supply frequency, and 25 to 60 deg C in ambient temperatures. This high degree of accuracy under such adverse conditions permits this device to be used in critical applications requiring an extremely rugged, yet accurate and sensitive instrument.

The system measures the resistances of two resistance thermometers, converts them to meter indications in degrees Fahrenheit, measures the difference between the two temperatures, and finally causes a relay to be energized when the difference exceeds a given magnitude.

The block diagram, Figure 1, shows how the signal originates as a variable resistance, R1 and R2, representing resistance thermometers. The amplifiers, RT1 and RT2, measure these resistances and put out currents which are metered by the two indicating meters M1 and M2. The output from the R/Ts also goes to a pair of bistable amplifiers which actuate the relays K1 and K2. The circuitry of the bistable amplifiers is such that when the signal from R1 is greater than that from R2, relay K1 is energized. When R2 is greater than R1, relay K2 is energized.

### Thermometer amplifier

The R/T amplifier measures the degree of unbalance of a Wheatstone bridge of which the resistance thermometer is one leg. The bridge unbalance current controls a simple saturable reactor which acts as preamplifier for the simple saturable reactor in the output stage. The output is metered to provide an indication of temperature and then goes on to the bistable temperature difference amplifiers.

Three wires were actually run in a cable to the resistance thermometer. This arrangement puts an equal amount of resistance in both legs of the bridge and hence nullifies the effect of the lead resistance. The bridge is balanced at a resistance corresponding to 50 deg F by varying R2. As the temperature (resistance)

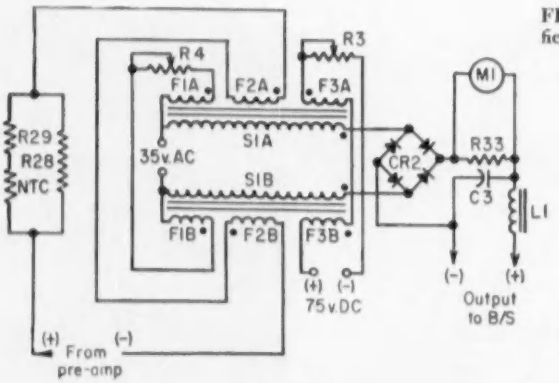
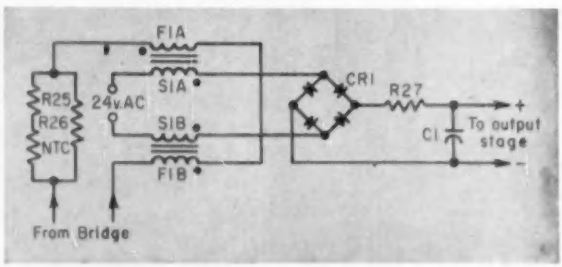
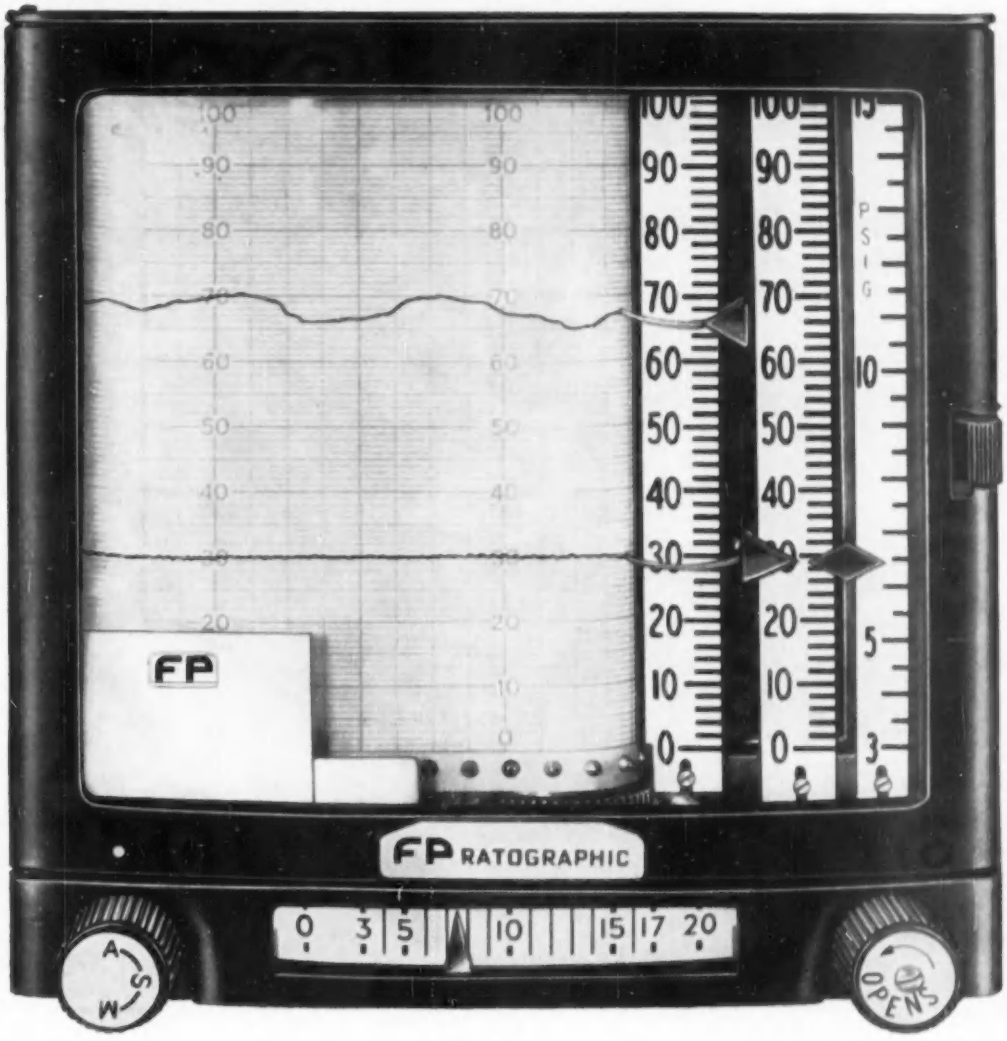



FIG. 3. Thermometer output amplifier is compensated saturable reactor.

FIG. 2. Thermometer preamplifier is simple saturable reactor.



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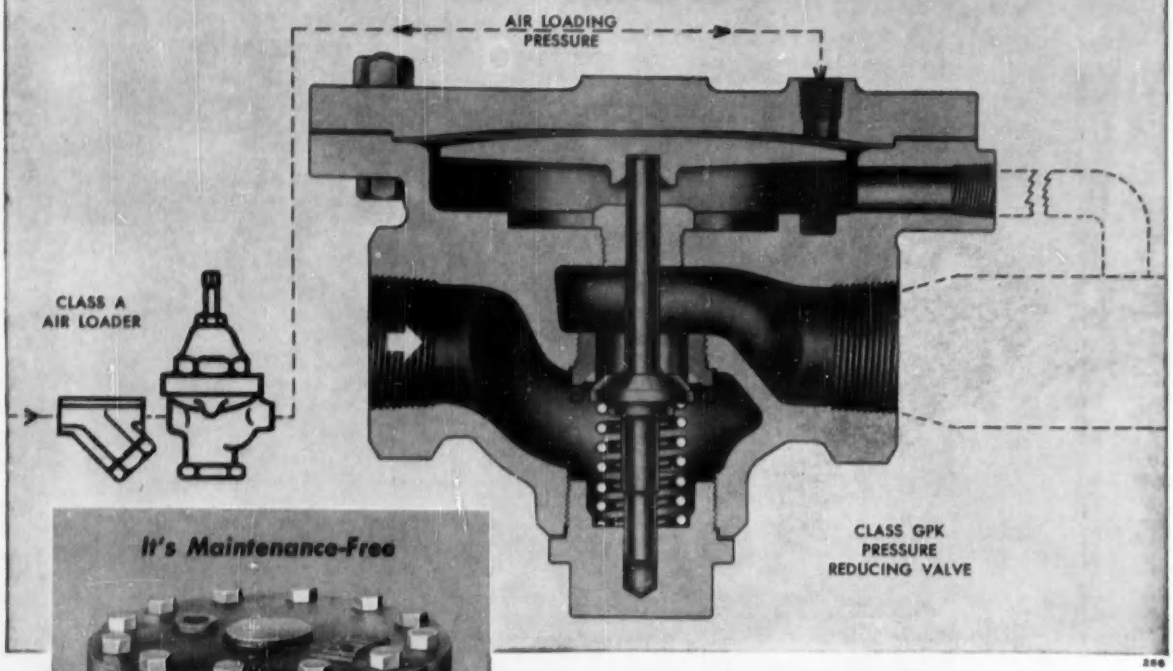



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increases, the bridge becomes unbalanced and a current flows through the preamplifier control winding directly proportional to the measured temperature. Since the bridge normally operates unbalanced, the output is directly proportional to the supply voltage and its accuracy will be no greater than the accuracy of regulation of the supply voltage. For this reason, the supply to the bridge was chosen to be 75 vdc regulated to ½ percent.

A simple saturable reactor was chosen for the preamplifier stage (Figure 2) since this type of amplifier is relatively insensitive to line voltage and frequency variations. The signal from the Wheatstone bridge enters the control windings (F1A and F1B) of the preamplifier through a temperature compensating network composed of R25, R26, and a negative temperature coefficient resistor (NTC). Thus, as the ambient temperature causes the resistance of the control winding to change, the resistance of the compensating network changes an equal amount in the opposite direction and the bridge sees a constant load.

With no signal on the control winding, the reactor will have a small output; this is the core's magnetizing current. Between values of control signals slightly greater than zero and values approaching the saturation current of the core, the output is a very linear function of the input. The two cores are oppositely wound, to make the amplifier respond only to the amplitude and not the polarity of the control signal. The output of the reactor, rectified by CR1, goes through an isolating network, R27 and C1, to the output stage.

The output stage, as shown schematically in Figure 3, is also a simple saturable reactor. It was chosen for the same reasons of stability and linearity as the preamplifier was. The control signal to the output stage is applied through a temperature compensating network (R28, R29, and NTC) similar in function to the network in the preamplifier. To counteract the quiescent output from the preamplifier, dc bias windings (F3A and F3B) are provided, and R3 is adjusted to supply an amount of ampere-turns of bias exactly equal and opposite to the ampere-turns of control signal coming from the preamp stage when the input to that stage is zero. In order to reduce further the quiescent, or zero-signal, output from the output stage, an ac bias is applied to windings F1A and F1B. This bias provides some of the magnetizing current for the core; the rest has to be supplied by the load current. Thus there will always remain some small magnitude of quiescent current. Since a dc signal is desired, the output is rectified by CR2 and filtered by the filter network R33, C3, and L1. The load current splits; most of it flows through R33 to the bistable amplifiers, but some of it flows through the indicating meter and provides the required temperature indication.

### THE BISTABLE AMPLIFIERS

Two bistable amplifiers are used in the actual system, but since their modes of operation are alike, only one need be described in detail here. The polarity of the control windings is so arranged that when temperature T1 is greater than temperature T2 by an amount (T1−T2) determined by the number of bias ampere-turns, the magnetic amplifier will saturate and relay (K1) will be energized. Similarly, when T2 is greater than T1, relay K2 will be energized.

The characteristics of a bistable amplifier are ideally suited for relay operation. It is positive; that is, it is either fully on or fully off. The transfer curve of this type of amplifier (Figure 4) illustrates this action. As the control current increases to point A, the amplifier follows the curve ABC. Since the curve has a negative slope, it is impossible to have a fractional output in the steady state. During the transient, as the amplifier saturates, the control current is actually forced to decrease. On decreasing control current, the amplifier output goes to minimum when the control current reaches point B; the output then describes the curve BAD. The difference in magnitude between the control current at A and B is known as the loop width and is directly proportional to the amount of positive feedback.

The bistable amplifier used in this application, Figure 5, is a conventional doubler amplifier with an excess of positive feedback; the required amount of positive feedback is supplied to windings F3A and F3B. The differential action is accomplished by the use of windings F1A, F1B, F2A, and F2B. As can be seen in the illustration, the windings energized by RT1 are opposite in polarity to those energized by RT2. Because of this arrangement of control windings, the net magnetomotive force that the cores see is directly proportional to the difference between the two control currents and therefore to the difference between the two temperatures. A pair of bias windings, F4A and F4B, is provided to set the level at which the cores saturate. The magnitude of the bias current determines the magnitude of the temperature difference required to saturate the amplifier.

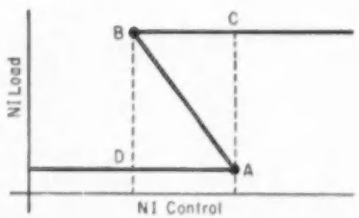



FIG. 4. Control transfer characteristic of bistable magnetic amplifier.

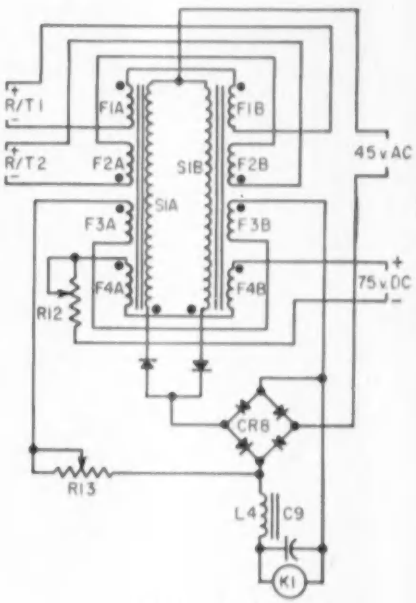



FIG. 5. Bistable amplifier.

Therefore, the amplifier is not only sensitive to the magnitude of the difference between the two signals, but also to its sign. Of the two amplifiers, each will operate its relay for only one condition. K1 will be energized when T1 is greater than T2, and K2 will be energized only when T2 is greater than T1.

Thus, the design objectives have been accomplished. The R/T amplifiers detect, amplify, and indicate the temperature signals and the bistable amplifiers perform the differencing action and trip the required relays.

IDEAS AT WORK

# A Function Generator for Two Independent Variables

**Analog generators of functions of two independent variables are usually slow and very expensive, or limited in terms of the kinds of functions they can generate. This approach makes use of inexpensive single-variable generators. In one form, it has operated at input frequencies up to 30 cps.**

**LEONARD TABACK**
**National Bureau of Standards**

In many analog computer studies it is necessary to represent empirical data by functions of several variables. This occurs frequently in the simulation of aircraft, where the parameters of flight equations are related nonlinearly to one or more of the variables of motion. To satisfy the requirements of an analog computer facility, the function generator must be economical, easy to use, relatively fast, and capable of generating a wide variety of arbitrary functions.

### Previous methods

There have been various schemes used for generating functions of two variables. Most of them lack some of the desirable characteristics mentioned above. One such scheme is the three-dimensional cam, upon which a pickup device is positioned axially and circumferentially by servos according to the independent variables x and y. The radial displacement of the pickup is determined by the contour of the cam, which is machined to represent the desired function of x and y. Machining is an expensive and troublesome job, and once finished, cannot be changed. The method is inherently slow because of its mechanical nature.

Another electromechanical scheme makes use of a set of ganged potentiometers, each potentiometer being shaped to represent one curve of the desired family of curves. The arms of these potentiometers are servo-positioned according to x. The outputs feed taps on an interpolating potentiometer. The arm of the interpolating potentiometer is servo-driven according to the input variable y, so that its output is a function of both x and y. This method has many of the disadvantages of the three-dimensional cam mentioned above.

Fully electronic schemes will, of course, increase the allowable speed of operation. One such scheme makes use of a matrix of selector circuits. The function generator is adjusted to the proper value and slope, at fixed increments of the input variables. Interpolation between these values, however, is generally nonlinear due to the on-off characteristic of the selector circuits. The variety of curves that can be fitted is limited because the function must be fitted into the rigid framework of the matrix. For example, if a 5-by-5 matrix is used, the best fit that can be obtained is a straight line across any one-fifth of the range, no matter how sharply the required function may be curved.

Another all-electronic scheme makes use of diode function-generators of a single variable. The slopes and breakpoints of the diode function generator are electronically controlled. This scheme requires a good deal of work to set up and is practical only for certain classes of functions.

### The new approach

The method of function generation to be described here alleviates many of the difficulties encountered in the schemes described in the literature. Basically, several function generators are used for one variable at successive fixed values of the other variable, and a scheme is provided for interpolating linearly between these functions. Interpolation can be made between function generators of any type or combinations of types. Such a technique is desirable because it can use any function generators available at a particular analog computer facility.

Figure 1 shows a block diagram of

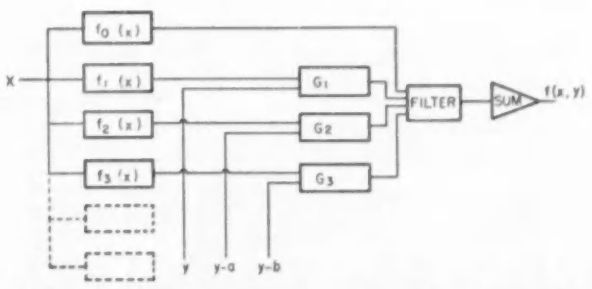



FIG. 1. Single-variation function. Generators at the left are gated by the value of y. Fractional values are interpolated automatically.

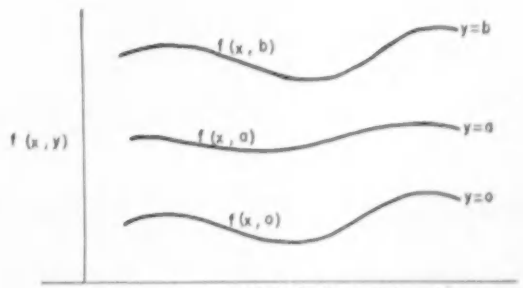



FIG. 2. Typical function of two independent variables, x and y.

# FREQUENCY STANDARDS

*3⅛" high
400 - 1000 cy.

**PRECISION FORK UNIT**
TYPE 50

*Size 1" dia. x 3¾" H.* Wght., 4 oz.*

Frequencies: 240 to 1000 cycles
Accuracies:—
Type 50 (±.02% at —65° to 85°C)
Type R50 (±.002% at 15° to 35°C)
Double triode and 5 pigtail parts required
Input, Tube heater voltage and B voltage
Output, approx. 5V into 200,000 ohms

**FREQUENCY STANDARD**
TYPE 50L

*Size 3¾" x 4½" x 5½" High*
*Weight, 2 lbs.*

Frequencies: 50, 60, 75 or 100 cycles
Accuracies:—
Type 50L (±.02% at —65° to 85°C)
Type R50L (±.002% at 15° to 35°C)
Output, 3V into 200,000 ohms
Input, 150 to 300V, B (6V at .6 amps.)

*3½" high
400 to 500 cy.
optional

**PRECISION FORK UNIT**
TYPE 2003

*Size 1½" dia. x 4½" H.* Wght. 8 oz.*

Frequencies: 200 to 4000 cycles
Accuracies:—
Type 2003 (±.02% at —65° to 85°C)
Type R2003 (±.002% at 15° to 35°C)
Type W2003 (±.005% at —65° to 85°C)
Double triode and 5 pigtail parts required
Input and output same as Type 50, above

**FREQUENCY STANDARD**
TYPE 2005

*Size, 8" x 8" x 7¼" High*
*Weight, 14 lbs.*

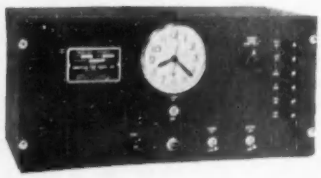
Frequencies: 50 to 400 cycles (Specify)
Accuracy: ±.001% from 20° to 30°C
Output, 10 Watts at 115 Volts
Input, 115V. (50 to 400 cycles)

**FREQUENCY STANDARD**
TYPE 2007T
**TRANSISTORIZED**

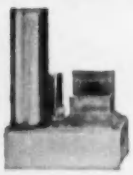
*Size 1½" dia. x 4½" H.* Wght. 7 ozs.*

Frequencies: 240 to 1000 cycles
Accuracies:—Same as 2003, above
Type 2007S—Silicon type
Input, 28V.
Output, Multitap, 75 to 100,000 ohms
*3½" in 2007S, 400 to 800 cycles.

**FREQUENCY STANDARD**
TYPE 2121A



*Size*
*8¾" x 19" panel*
*Weight, 25 lbs.*
Output: 115V
60 cycles, 10 Watt
Accuracy:
±.001% from 20° to 30°C
Input, 115V (50 to 400 cycles)



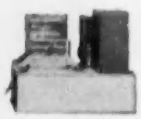
**FREQUENCY STANDARD**
TYPE 2001-2

*Size 3¾" x 4½" x 6" H., Wght. 26 oz.*

Frequencies: 200 to 3000 cycles
Accuracy: ±.001% at 20° to 30°C
Output: 5V. at 250,000 ohms
Input: Heater voltage, 6.3 - 12 - 28
B voltage, 100 to 300 V., at 5 to 10 ma.

**FREQUENCY STANDARD**
TYPE 2111C

*Size, with cover*
*10" x 17" x 9" H.*
*Panel model*
*10" x 19" x 8¾" H.*
*Weight, 25 lbs.*
Frequencies: 50 to 1000 cycles
Accuracy: (±.002% at 15° to 35°C)
Output: 115V, 75W. Input: 115V, 50 to 75 cycles.



**ACCESSORY UNITS**
for TYPE 2001-2

L—For low frequencies multi-vibrator type, 40-200 cy.
D—For low frequencies counter type, 40-200 cy.
H—For high freqs, up to 20 KC.
M—Power Amplifier, 2W output.
P—Power supply.

*This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government departments, armed forces—where maximum accuracy and durability are required.*

WHEN REQUESTING INFORMATION
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## American Time Products, Inc.

580 FIFTH AVENUE, NEW YORK 36, N. Y.

the system arrangement. Blocks G are voltage-controlled pulsed attenuators, whose transfer functions may have any value between zero and one depending on the input variable y. The output of this system is:

$$(x, y) = f_0(x) + G_1 f_1(x) + G_2 f_2(x) + \ldots \quad (1)$$

with the values of $G_1$, $G_2$, . . . as follows:

$$G_1 = \frac{y}{a} \text{ for } 0 < y < a$$

$$0 \text{ for } y < 0$$
$$1 \text{ for } y > a$$

$$G_2 = \frac{y - a}{b} \text{ for } a < y < (a + b)$$

$$0 \text{ for } y < a$$
$$1 \text{ for } y > (a + b), \text{ etc.}$$

Now consider the curves in Figure 2, each for a y-value held at an arbitrary constant. In order to obtain $f(x, y)$ of Figure 1, the following equations must be satisfied.

$$f_0(x) = f(x, 0)$$
$$f_1(x) = f(x, a) - f(x, 0)$$
$$f_2(x) = f(x, b) - f_1(x)$$

Thus the settings of the three (or more) function generators are specified: $f(x, y)$ for values between $y = 0$ and $y = a$ is given by

$$f_0(x) + \frac{y}{a} f_1(x)$$

Similar equations hold for values of y between $a$ and $b$, $b$ and $c$, etc., and linear interpolation between successive arbitrary y-values is obtained.

The equations are general and the function $f(x, y)$ may be set up using any desired y increment. However, it is simpler to set the function generators for equal increments $K$. Equation 1 then reduces to:

$$f(x, y) = f_0(x) + \frac{y}{K} f_1(x) + \frac{y - K}{K} f_2(x) + \ldots$$

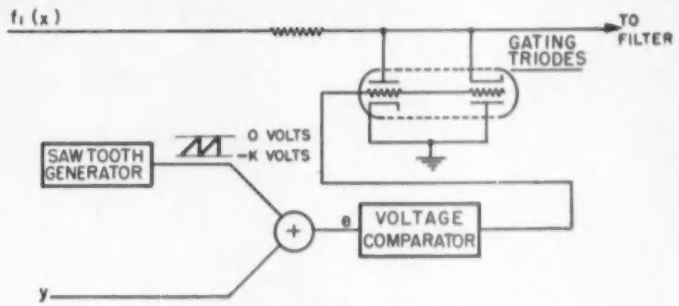



FIG. 3. Circuit for voltage-controlled attenuators—blocks G of Figure 1.

and the inputs to the attenuators become y, y − K, y − 2K, etc.

**Voltage control**

The method of obtaining a voltage-controlled attenuator will now be described. Figure 3 shows a block diagram of the operation for $G_1$. The output of the voltage comparator can be in one of two states, 0 volts or −100 volts. The output is zero whenever e is negative and −100 whenever e is positive. Thus, rectangular output pulses, whose widths are proportional to y, are produced at the frequency of the sawtooth. The pulse width may vary from full on to full off. These pulses are used to turn the gating triodes on and off. Thus the output of the gate is a pulse train with an envelope corresponding to $f_1(x)$ and a pulse width proportional to y. For $y = 0$ to $y = K$, the average value of the pulse train is $y/Kf_1(x)$. The gain in this channel varies linearly with y from 0 to 1 and then remains at 1. This circuit then satisfies the requirement for $G_1$ outlined above. By the addition of a sufficient number of function generators and voltage-controlled attenuators, almost any arbitrary function of two independent variables may be instrumented.

Such a system has been constructed in the National Bureau of Standards Computer Laboratory with single-variable function generators using diode circuitry, and has been found to operate satisfactorily with a sawtooth frequency of approximately 10 kc. A typical model provides eight segments having adjustable slope and breakpoints. Such function generators are used in many analog computer facilities. They are quite flexible, reliable, and commercially available from most manufacturers of analog computing equipment.

The advantages of the described system are:

(1) Easy setting—each function generator may be set independently. Advantage may be taken of the movable breakpoints so that many segments may be used in fitting the rapidly changing portions of a curve and fewer segments in relatively straight portions.
(2) Interpolation is linear—however, the interpolation may be made nonlinear in a prescribed fashion by shaping the sawtooth.
(3) There is no limitation on the types of curves which can be fitted, as long as the frequency components are within range.
(4) Functions once set are easily changed.

# Do-It-Yourself Precision Function Pots

**MORTON P. MATTHEW and KENNETH F. CHANNON**
**The Ahrendt Instrument Co.**

**Resistance film potentiometers can be trimmed by secondary resistances much as wire-wound potentiometers. The technique described for developing the film shape for a given function should be valuable to those who need a special potentiometer quickly. Functions can be matched readily to 0.1 percent.**

Conducting films, being used increasingly for resistors and potentiometers, offer advantages of infinite resolution, simplicity of design, compactness, and low cost. Film techniques have been applied to both linear and nonlinear potentiometers, the latter generally using shaped films for the resistance elements.

Accuracy limitations can be a problem with film potentiometers, requiring close control of the film deposition and shaping. If a fair degree of

# How to get maximum combustion efficiency . . . measure both combustibles and oxygen

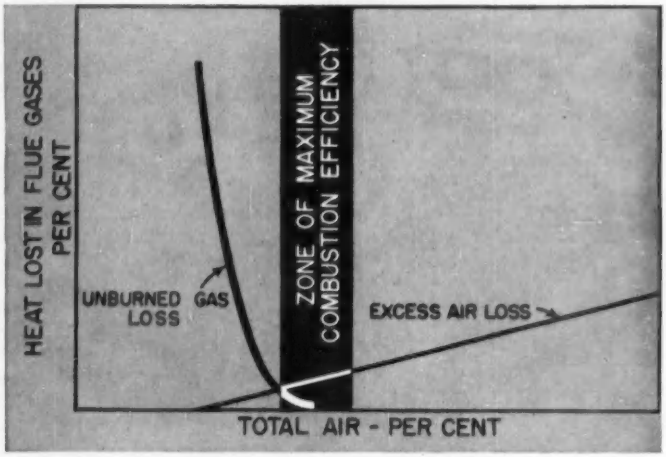
Simultaneous measurement of both oxygen and combustibles is needed to obtain optimum combustion. No instrument that measures only one of these two interdependable factors can give you the full information necessary.

Now, Bailey offers two units, each giving a continuous and simultaneous double check on combustion efficiency: a permanent analyzer-recorder which records both factors on a single chart; and a new light weight, portable unit which indicates both factors.

Both instruments measure: (1) excess air—regardless of the fuel or combinations of fuel being burned. (2) mixing efficiency of your fuel burning equipment by showing per cent combustibles in the flue gas.

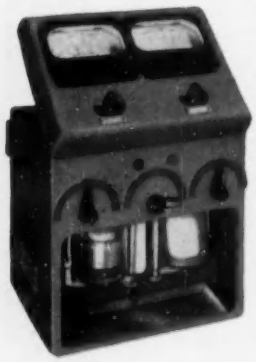
Both units are designed to increase efficiency in the furnace operations of the steel industry, on glass tanks, cement and lime kilns, ceramic and refractory kilns, steam boilers and also on direct and indirect-fired furnaces in the metal processing industries.

To prevent your money from becoming waste gas, look into these two efficiency provers. A Bailey engineer will be glad to give you details or write us for product specifications.




Maximum Combustion Efficiency is secured by keeping the sum of Excess Air Loss and Unburned Gas Loss to a minimum. To do so by the direct method simply measure both oxygen and combustibles in flue gas.

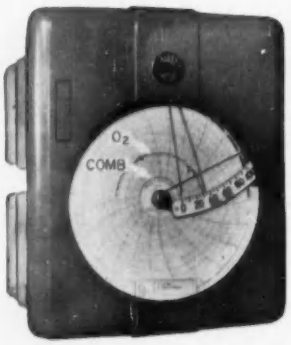
## For portable use—
## HEAT PROVER Analyzer



The famous Cities Service HEAT PROVER analyzer is now Bailey built and sold. Weighing only 25 pounds, it is a self-contained automatic analyzer including a sampling tip and hose plus a thermocouple for temperature measurement.

Instrument dials are dual range for greater accuracy and sensitivity.

## For permanent installation
## Oxygen-Combustibles Recorder




The Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart. These records enable the operator to keep fuel burning equipment performing continuously in the zone of maximum combustion efficiency. Excess air may be reduced to the point where combustibles begin to show.

G 40-1

*Instruments and controls for power and process*

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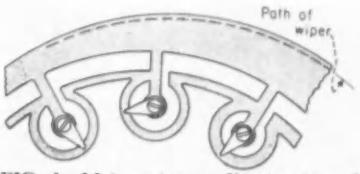


FIG. 1. Main resistance film is trimmed by parallel "rheostats".

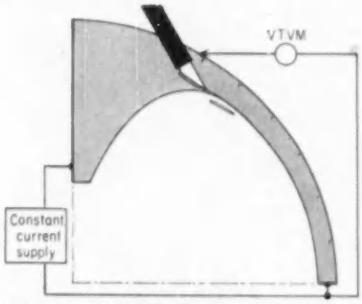


FIG. 2. Facsimile paper film can be trimmed with knife as shown.

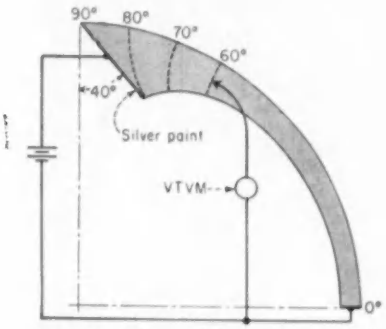


FIG. 3. Silver paint simulates infinite width film. Constant voltage contours easily traced.

precision is required, production methods must be supplemented by individual shaping of the film on each unit. This has been done automatically by a servo-controlled milling operation which reads the voltage as the element is rotated and trims the film outline to bring it within the desired electrical tolerances.

A patent has been applied for on a potentiometer in which the deviations of the basic film element are corrected by secondary films in the form of adjustable padding resistors. Figure 1 indicates a portion of such a potentiometer film. The main element, varying in width if nonlinear, is wiped by a brush at its outer circumference. The inner edge of the film has branches connected to arc-shaped film paths which, with their own wipers, act as small rheostats. These rheostats are adjusted to parallel more or less resistance between branches, thus altering the voltage distribution along the main resistance film.

Wire-wound potentiometers have in many instances been tapped and shaped or trimmed by such secondary resistances. Applying this principle to the trimming of a film potentiometer permits both main and secondary resistances to be laid down in the same operation as a single film.

To verify theories and develop the film shape of at least one typical nonlinear potentiometer, experiments were made using conducting paper for the film element. Teledeltos paper, used for facsimile reproduction, proved eminently satisfactory for this. It has a resistance of about 2,500 ohms per square (inch, centimeter, or anything) along the grain. Cut and try methods, working to a scale of about 5 to 1, quickly won out over calculation in arriving at a film shape for a sine potentiometer. In fact, connecting the paper to a constant current source and cutting it with a sharp blade while reading voltages along the edge, turned out to be a quick and effective method (see Figure 2). With the constant current, no shaping of the upper end will change the IR drops already established along the lower end, and the paper may be cut progressively from bottom to top to give the voltage characteristic wanted. Moreover, the final resistance value may be predicted: the constant current is known; the resistance paper is cut according to a desired voltage distribution, including the overall voltage; and the overall resistance has to obey Ohm's Law.

It was found that low resistance paths can play as important a part as high resistance paths. Where the sine function approaches zero slope, at 90 deg, an infinite film width is theoretically required. The effect is correctly achieved, however, with a conducting line (silver paint was used in the experiments) sloping back from the 90-deg point at about 40 deg, as shown in Figure 3.

The resistance paper was invaluable in showing (1) the negligible distorting effect of the branch connections to the main film, and (2) where the branches should be placed. Exploring the paper field with a probe quickly showed the equipotential lines and led to the proper points at which to parallel the trimming resistances (Figure 3).

One quadrant of a 10-in. diameter Teledeltos paper sine-function potentiometer was constructed, complete with adjustable secondary branches every 10 deg, and was actually brought within an accuracy of 0.1 percent. Figure 4 shows a photograph of the model, somewhat cluttered due to adding silver paint to "sharpen" the trimming resistances.

The model showed that it is practical to shape a film for a nonlinear potentiometer to a moderate accuracy, and trim it with its own "bootstraps" to a higher accuracy. It also showed, incidentally, that near 90 deg a small error in film shape causes such a negligible error in the voltage distribution that one or two trimming resistances may be skipped in this region. It is interesting to speculate how effective a "paper pot" might actually be in some (nonmilitary) application.

In translating results from paper to practice, account should be taken of the slight nonorthogonality of the facsimile paper. Resistance along the grain is about 90 percent of the resistance across the grain. For example, a film shape could be cut out twice, the second time with the grain turned 90 deg, and the mean between the two would approach the true shape.

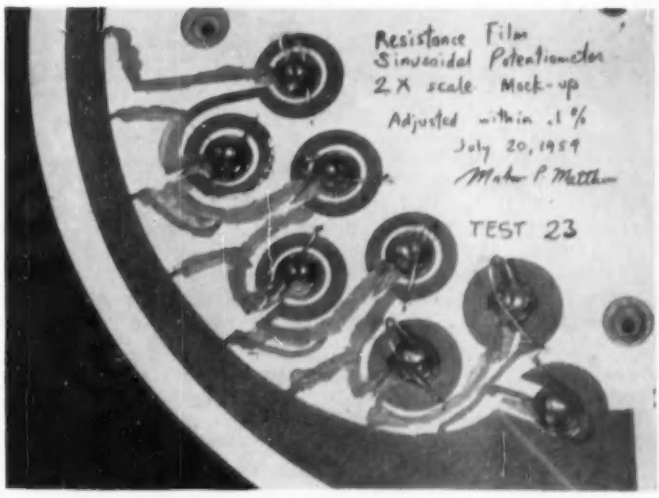


FIG. 4. This pot matches sine function to 0.1 percent.

# L&N pH Control takes the bite out of acid-tainted waste

**The cooling water** pictured is intermittently contaminated by the acid operations of a large metals producer. When this occurs, it's piped to an acid leak lagoon, with other wastes such as washwater from acid tank-cars. But when discharged, the combined waste is in close-to-neutral condition, thanks to an L&N pH Control System— electrode assembly, Speedomax® recorder, Control Unit, Valve Drive.

Although L&N pH equipment is taking the bite out of this highly acid effluent, merely purchasing the equipment didn't assure successful treatment. The first and most important step was a critical look at existing treatment facilities via L&N's unique pH Controllability Analysis. This appraisal of "controllability factors" such as flow, concentration, retention, tells L&N specialists whether a process is actually controllable within the pH limits required, or what must be done to *make* it controllable. They translate these data into the answers you need to engineer an efficient treating system.

Process Data Sheet 700(2) explains this unique, successful L&N approach to pH control in industrial waste treatment. Write Leeds & Northrup Company, 4918 Stenton Ave., Phila. 44, Pa.

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Instruments — Automatic Controls • Furnaces

*Jrl Ad ND46-96(4)*

# Permanent Magnet Calibrates Temperature Indicators

**This calibrator uses a single reference junction held at constant temperature. Higher temperatures are simulated by adding precision millivoltages to the reference junction voltage. The incremental millivolts are referenced to a magnetic standard.**

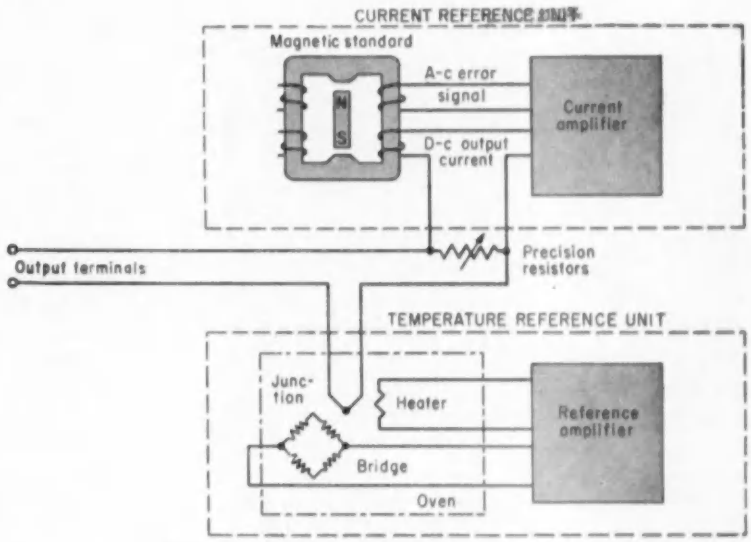
**PAUL B. ROBINSON**
**General Electric Co.**

A calibrator for precision temperature indicators usually requires a thermocouple held at a reference temperature in an ice bath, a millivolt source, and a precision potentiometer to measure the millivolts. A comparison of these millivolts with the thermocouple curve gives the effective temperature seen by the indicator. Here the ice bath and the pot have been eliminated, the first by referencing the thermocouple to one specific temperature with a resistance bridge reference unit, and the second by introducing into the thermocouple circuit millivolts corresponding to specific temperatures different from the reference. These were obtained from a constant-current dc generator.

A permanent magnet standard is the reference for the constant current generator, which develops the millivoltage increments across precision resistors placed in series with the reference thermocouple.

The calibrating thermocouple is referenced to 100 deg C by the same reference junction unit used in GE's Type HE round chart recorders. This unit maintains the reference temperature to within 0.5 deg C; it is shown at the bottom of the diagram.

At the bottom left is the oven in which the thermocouple junction is enclosed. The oven is heated by power from the output of an amplifier. The amplifier gets its input signal from a resistance bridge that is also inside the oven and close to the thermocouple. The bridge is designed to be in balance at the reference temperature, so that any departure from this changes the heat supplied to the oven. The loop gain in the system is high enough so that ambient temperature has little effect on the reference temperature. This last small effect is reduced virtually to zero by ambient temperature compensation in the bridge.




**Calibrator for temperature indicators produce precise millivoltages corresponding to the specific kind of thermocouple at various temperatures.**

The millivolt increments corresponding to higher temperatures are provided by passing a precise dc current through precision resistors in series with the reference thermocouple. Switching in different resistors gives different values of effective thermocouple temperature.

### Magnetic standard

The constant current is supplied by the combination of a magnetic standard and a voltage amplifier shown at the top of the diagram. The magnetic standard is basically a device which compares the flux produced by a direct current with that component of flux produced by a permanent magnet along a fixed axis. When the two fluxes cancel exactly, the output signal of the magnetic standard is zero. When the fluxes do not cancel, an ac error signal is produced. The signal is amplified, converted to dc in a phase-sensitive rectifier, and filtered. The signal is then further amplified by a dc amplifier, whose output is the required dc current. This current is then passed through the precision reference resistor and the magnetic standard's dc input in series.

Thus, the magnetic standard and amplifier combination regulates the current to a value exactly corresponding to a component of the magnet's flux. It does this within 0.05 percent despite ambient temperature and line voltage variations. The magnetic standard is normally used with a movable magnet, giving a current linear with position. In this application, however, the magnet was locked to produce a single value of current.

The combination of the temperature reference and precision millivolt source provides a calibrating circuit that is capable of simulating any desired temperature by proper selection of precision resistors. Also, it can operate with any thermocouple material by selection of the oven unit.

# NEW PRODUCTS

LISTING IN GROUPS



*as seen at ISA show . . .*


## P-E-P SYSTEM for accurate transmission.

A new pneumatic-electric-pneumatic transmission system features long life and high accuracy. No tubes, transistors, or intermittent contacts are used. The transmitter requires a low voltage dc supply and a 3-to-15-psi input signal pressure. A change in the input signal causes a change in the electrical resistance of a force-sensitive element in the transmitter, and this in turn causes a change in the transmission current necessary to restore the balance. A dc current output of 3 to 15 ma is directly proportional to the 3-to-15-psi input signal. The receiver is very similar in construction, and its function is just the reverse. Maximum error below plus or minus 0.25 percent.—Robertshaw-Fulton Controls Co., Philadelphia, Pa.

**Circle No. 1 on reply card**


## DIGITAL PRESSURE SYSTEM just out.

The digital pressure system shown here represents the latest addition to a group of systems that can be developed from a limited number of "building block" components. Pressures are sensed by a miniature electronic transducer, or Vibotron Digital Gage, which converts them into an electrical frequency related in bandwidth to the pressure range.

Systems can be arranged for sequential or simultaneous multi-point measuring and recording of pressures, for pressure ratio computing, and for high-speed recording of a single pressure to produce an optimum data time plot. Output is presented as a visual display or, if desired, a printed readout. In monitoring applications, the information may be used for control purposes.—BJ Electronics, Borg-Warner Corp., Santa Ana, Calif.

**Circle No. 2 on reply card**


## FROM DC TO 2,000 CPS without compensation.

Called the Viscorder, this new direct-reading oscillograph is said to achieve a flat frequency response to 2,000 cps without peaked amplifiers or any other kind of compensation. The instrument records directly on paper, thus eliminating the need for powder magazines or other processing. It contains six channels on 6-in.-wide paper plus provisions for two timing traces. Traces are not limited by adjacent channels; each is capable of a full 6-in. deflection peak to peak. Possible recording speeds are 0.2, 1, 5, and 25 in. per second, minute, or hour. For most of its applications, no amplification at all is required. Sensitivity is comparable to photographic-type units.—Minneapolis-Honeywell Regulator Co., Denver.

**Circle No. 3 on reply card**

## IBM'S NEW RAM for the office . . .

Combining the storage capacity of magnetic tape with the speed of random access, this new memory unit solves the problem of continuous or in-line accounting. As shown in the top photo, the RAM file consists of 50 magnetic discs arranged in a vertical stack. Both sides of each disc contain 100 recording tracks and each track holds five 100-character records. These records flow to and from the memory on an electronically controlled access arm. The entire stack rotates at 1,200 rpm, while the arm moves up and down and between records to reach a particular record in less than a second. In effect the memory stores the equivalent of 50,000 100-column master and balance cards, any one of which can be obtained without scanning through intervening records.

Following the development of the memory unit, a brand new data processing system was built. Called the RAMAC (Random Access Memory Accounting machine), the system consists of: Processing Unit containing a magnetic drum for working storage, a magnetic core buffer memory, and control circuits for data handling and arithmetic; a Printer for the automatic preparation of reports on continuous forms; a Card Punch, used only as an output device, for taking data from the drum memory in the processing unit; and a Console control center which houses the reader for a punched card input and from which the operator can interrogate the memory unit. The bottom photo shows the complete RAMAC system.

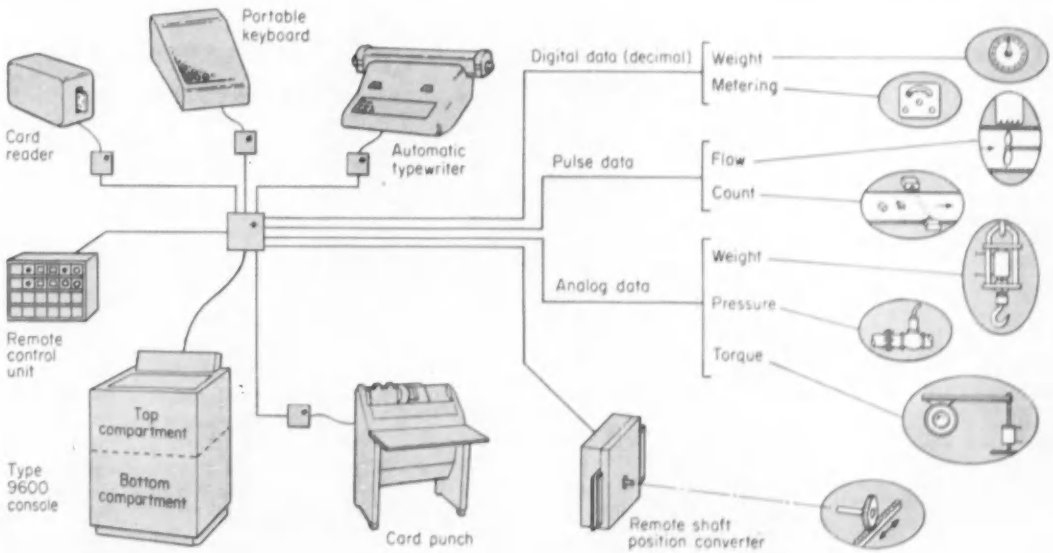
The well-known Type 650 magnetic drum data processing machine is also available now with up to four of these RAM files, giving it a total of 24 million digits of random access memory. Ten remote inquiry stations may be connected to the RAM 650 system through a 500-ft circuit. Any of these stations may be used to enter data into a disc memory or to interrogate the memory, and provides automatic typewritten response.

**Circle No. 4 on reply card**


## . . . and APR for the plant.

Modular design of IBM's new Automatic Production Recording (APR) systems permits appropriate combinations of component parts for the efficient handling of a wide variety of production data. The Type 9600 Console contains a control unit, an automatic typewriter, and a commutator clock in the top, and up to six component panels and a power supply in the lower compartment. Other externally connected components and possible applications are shown in the schematic below.—International Business Machines Corp., New York.

**Circle No. 5 on reply card**



## NEW PRODUCTS

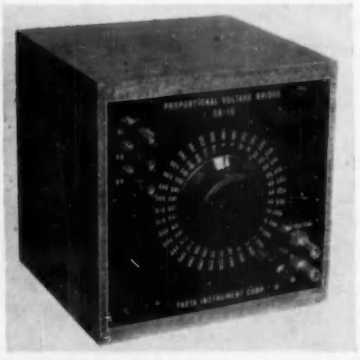
# RESEARCH, TEST & DEVELOPMENT

**as seen at ISA show . . .**

### DIGITAL MULTIMETER

Positive or negative voltages from 0.01 to 1,000 volts ac or dc, and resistances from 10 ohms to 10 megohms are readily measured by this new digital multimeter. Compact and portable, the instrument has three manually selected ranges, each with a sensitivity of 0.1 percent. All values are digitally displayed to three places. The reading rate of 20 readings per second permits monitoring rapidly varying voltages without the phase lag characteristics of D'Arsonval-type meters. Vertically positioned printed circuits and a built-in fan assure cool operation.–Franklin Electronics, Inc., Bridgeport, Pa.

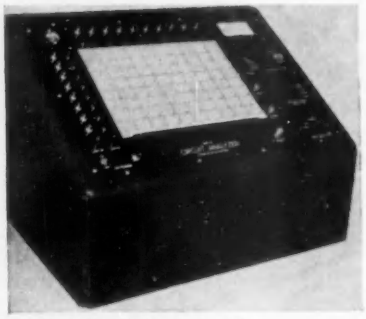
**Circle No. 6 on reply card**



### SYNCHRO BRIDGE

The principle applications of this proportional voltage bridge are the measurement of synchro electrical error and accuracy of position servos. The bridge is a passive comparison device of high accuracy. To attain precision, its resistors are carefully aged, sealed in oil, and matched against NBS primary standards. Each of its three arms has 50,000 ohms resistance. Angular accuracy is within 10 sec of arc. Rotation is in steps of 5 deg, continuous through 360 deg.–Theta Instrument Corp., East Paterson, N. J.

**Circle No. 7 on reply card**



### CIRCUIT ANALYZER

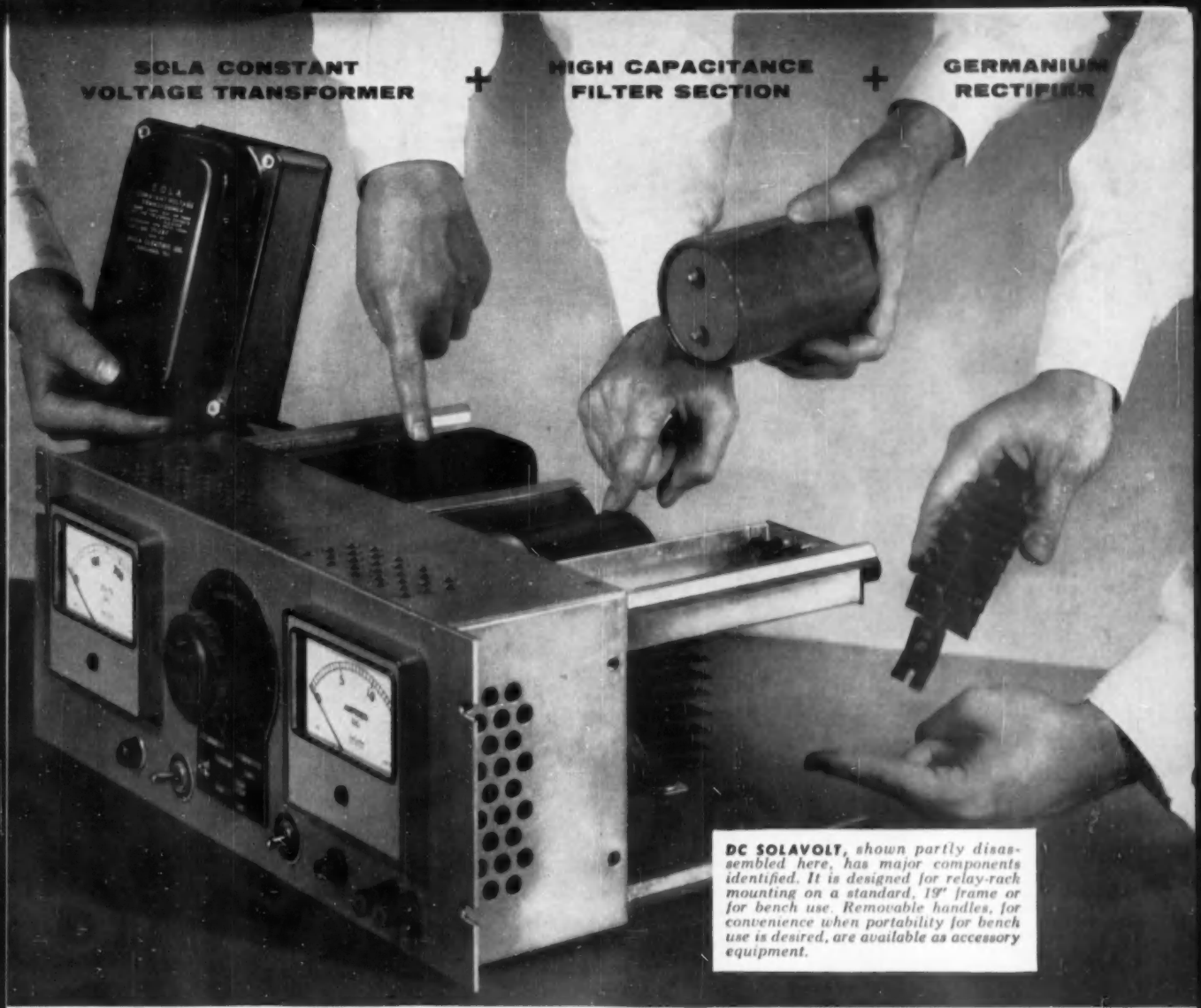
This compact electrical circuit analyzer tests 80 circuits in just 8 sec. Highly flexible, it can test for all types of errors, functionally test relays, solenoids, and other devices, and will test any interconnected cable system for continuity, shorts, and insulation resistance. Manufacturer claims that nontechnical personnel can master its operation in 30 min. or less. The unit will define continuity to the point of rejecting ½-ohm continuity resistance as an open circuit at currents up to 2 amp, and will define leakage resistance to the point of rejecting 0 to 200 megohms as a direct short.–DIT-MCO, Inc., Kansas City, Mo.

**Circle No. 8 on reply card**

### FUNCTION GENERATOR

A new 5-channel diode function generator is completely self-contained except for relays and reference supplies. Ten-turn potentiometers and 1,000-division dials for both "break point" and "slope" allow the direct generation of slopes up to 12 without paralleling of segments. Resolution is excellent, and functions once set up can be reproduced later by simply resetting the dials. The number of segments in each channel may be varied according to the function being generated. A calibration circuit on the control panel permits a function to be set up quickly from a simple plot of the function, eliminating the need of an external plotting board.–Reeves Instrument Corp., New York, N. Y.

**Circle No. 9 on reply card**




**DC SOLAVOLT,** *shown partly disassembled here, has major components identified. It is designed for relay-rack mounting on a standard, 19" frame or for bench use. Removable handles, for convenience when portability for bench use is desired, are available as accessory equipment.*

# Unique combination of components in adjustable "DC Solavolt" regulated power supply reduces conventional size, weight, and cost

Compact size, low weight, high efficiency, and moderate price distinguish the new "DC Solavolt" from conventionally-designed, regulated, adjustable dc power supplies. These outstanding advantages have been secured by using a unique assembly of components (shown above) that occupy only 7" of height and 12¼" of depth on a standard, 19" relay rack frame.

Along with design simplicity, the "DC Solavolt" provides laboratory standards of performance:

**OUTPUT VOLTAGE REGULATED WITHIN ±1%** at full load with supply voltage variations up to ±15%. (Regulation within ±1.5% at 50% load and lowest voltage setting.)

**RIPPLE VOLTAGE HELD WITHIN 0.10%** (rms) at full load and nominal input voltage.

An important feature of this adjustable dc power supply is its ability to handle transient or "pulse" loads of up to twice the full load rating of the supply. The "DC Solavolt" has no tubes to replace, requires no "compensating" or "zero" adjustments, and needs no maintenance.

Six stock models provide outputs *adjustable in voltage ranges between 5 and 400 volts and load-currents up to 7 amperes.* Your local electronic distributor now has the "DC Solavolt" in stock. He will be happy to give you further, technical information.

**SOLA** *Constant Voltage* **DC POWER SUPPLIES**

**Write for Bulletin 26K–DC-245**
**SOLA ELECTRIC CO.**
**4633 W. 16th Street**
**Chicago 50, Illinois**

CONSTANT VOLTAGE TRANSFORMERS • FLUORESCENT LIGHTING BALLASTS • MERCURY VAPOR LIGHTING TRANSFORMERS
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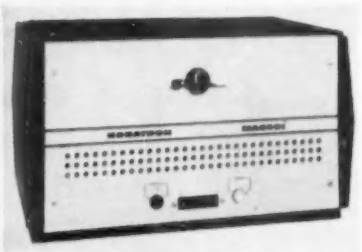
## NEW PRODUCTS

### VIBRATION ANALYZER

The portable instrument pictured above will measure the acceleration, velocity, and displacement of mechanical vibrations from 3 to 20,000 cps. It measures displacements as small as 0.0001 in. and as great as 3.0 in.; velocities from 0.03 in./sec to 1,000 in./sec; accelerations from 10 in./sec/sec to 300,000 in./sec/sec (0.03 g to 780 g). It can also be used with an oscilloscope for the quantitative analysis of impact shock and impulsive motions. A polarity switch is provided for determining positive and negative peaks of vibration.—Televiso Corp., Des Plaines, Ill.

**Circle No. 10 on reply card**

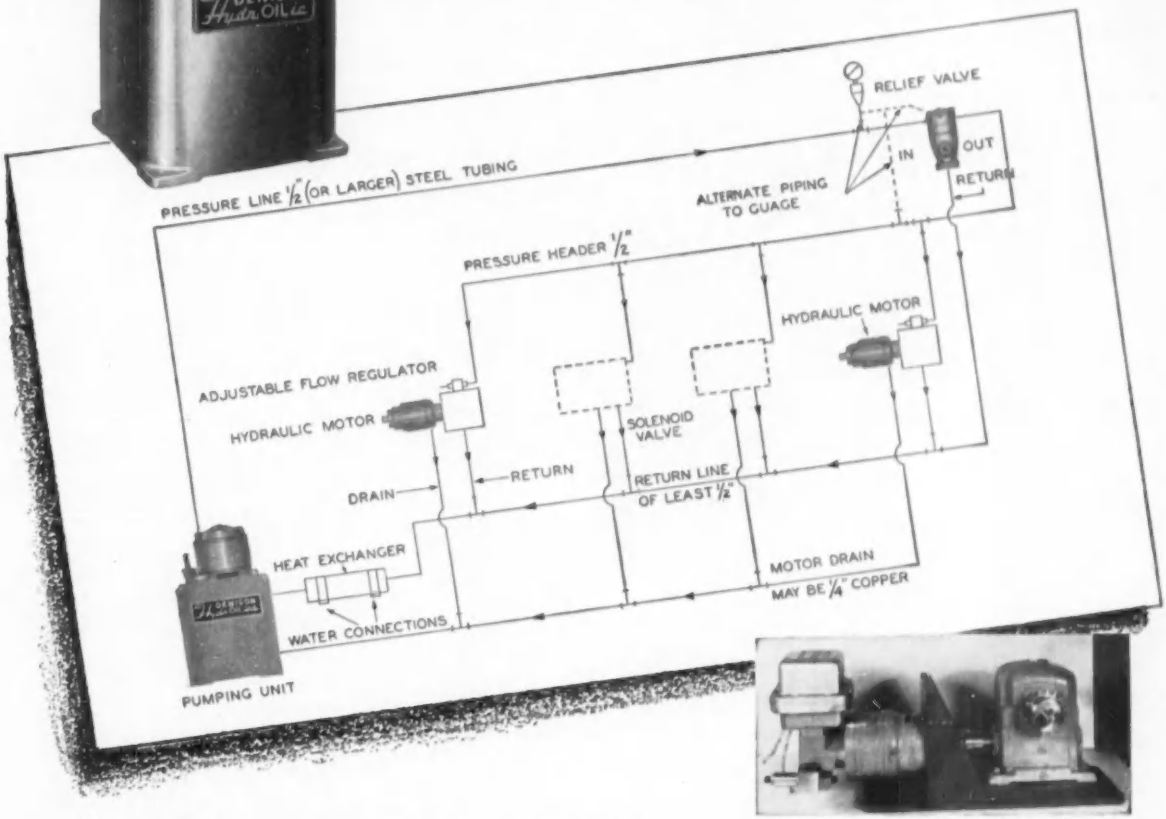


### TUBELESS DC SOURCE

The transistorized circuit employed in this new dc source is said to be reliable, rugged, and precise. A silicon diode is used as reference element, and a temperature-compensated transistor amplifier provides control current for the magnetic amplifier. Input voltage range is 105 to 125 vac, single phase, 60 cycles. There are three output voltages: 6 vdc, internally adjustable by plus or minus 5 percent, 5 amp load; 6 vdc, 100 ma load; and 2 vdc, 40 to 60 ma load.—Sorensen & Co., Inc., Stamford, Conn.

**Circle No. 11 on reply card**


# Four-color printing register controlled within .002 inches with Denison Hydraulic Equipment






Each compensator idler is driven from the sprocket of this gear reducer which is driven by the Denison axial-piston fluid motor. A solenoid valve controls motor operation in response to signals from the compensator amplifier. (Below) Selector switches mounted on the end of each print cylinder shaft generate electrical signals to indicate the angular position of the cylinder.

Did you ever notice how one color overlaps another on the Sunday comic pages?

Getting colors to register properly on high-speed presses is one of the most difficult tasks in modern printing. But the HURLETRON register control system, developed by Electric Eye Equipment Company and powered by Denison hydraulic equipment overcomes the problem . . . actually controls register within .002 of an inch.

Denison hydraulic pumps and motors respond instantly to electronically-developed signals, a major factor in the pinpoint accuracy of Electric Eye's control system. Only one hundredth of a second is required for an adjustment to be made.

The key to the entire system is a Denison fixed displacement, high pressure, high volume vane pump. Denison's fluid axial-piston motor and Multi-Range Flow Control contribute to the highly dependable operation of this printing aid.

Hundreds of similar experiences by equipment manufacturers prove how Denison hydraulic pumps and motors solve difficult control problems with unusual simplicity. Write for full details.

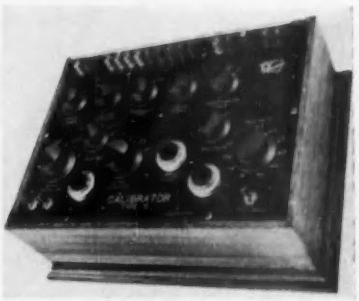
**DENISON ENGINEERING DIVISION**

*American Brake Shoe Co.*

1247 Dublin Road • Columbus 16, Ohio

**DENISON HydrOILics**

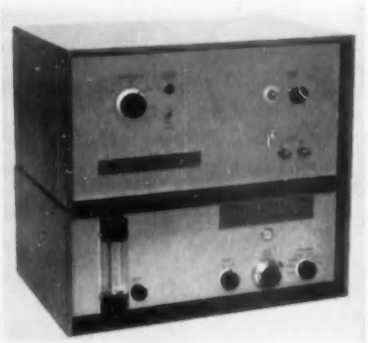
## NEW PRODUCTS



### CALIBRATOR

This versatile instrument may be used for the calibration of wire strain gages, their transducers, and thermocouples. It requires no complicated hookup to calibrate one-, two-, or four-arm systems. The instrument uses the electrical equivalent method of calibration and saves time by making dead-weight testing necessary only once for each transducer. Applied loads are read directly in force, acceleration, torque, pressure, etc., and tedious arithmetic is eliminated in linearity checks. Accuracy is within plus or minus 0.05 percent, while the total thermal emf is less than 3 microvolts.—Allegany Instrument Co., Metuchen, N. J.

**Circle No. 12 on reply card**



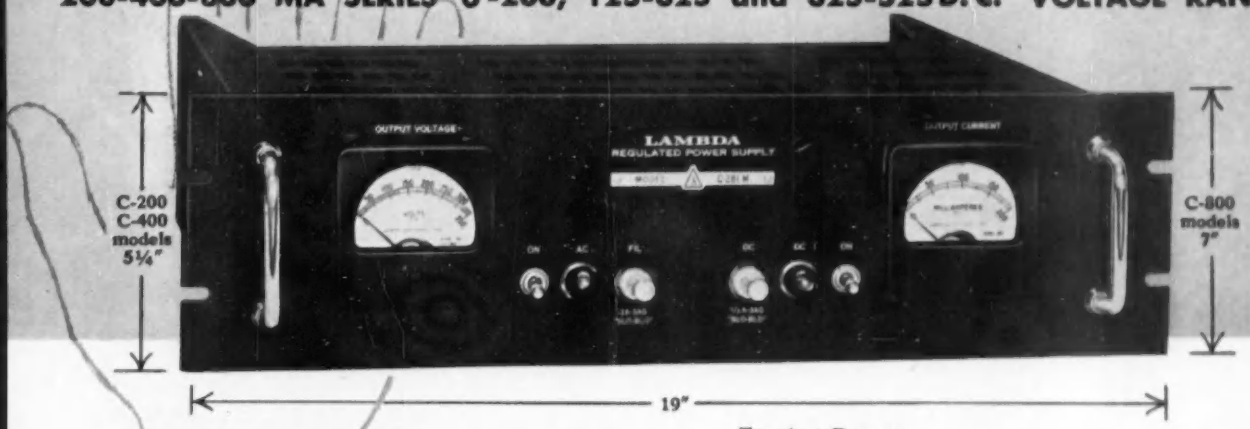
Utilizing the elution method, a new vapor phase chromatograph will handle a variety of compounds including liquids with boiling points up to 325 deg C. The instrument consists of two units. The analyzer unit (top) contains the sample introduction system, chromatographic column, thermostatic heating system, and detector. The control unit (bottom) contains the power input and distribution system, carrier gas flow controller, and detector circuit con-

## save panel space with LAMBDA d.c. power supplies

# NEW COM-PAK* SERIES

*trademark

## 200-400-800 MA SERIES 0-200, 125-325 and 325-525 D.C. VOLTAGE RANGES




### COM-PAK MODELS RANGES AND PRICES

| Model[1] | Output Voltage[2] | Output Current[3] | Base Price[1] |
|---|---|---|---|
| C-280 | 0-200 VDC | 0-200 MA | 184.50 |
| C-281 | 125-325 VDC | 0-200 MA | 159.50 |
| C-282 | 325-525 VDC | 0-200 MA | 169.50 |
| C-480 | 0-200 VDC | 0-400 MA | 259.50 |
| C-481 | 125-325 VDC | 0-400 MA | 244.50 |
| C-482 | 325-525 VDC | 0-400 MA | 259.50 |
| C-880 | 0-200 VDC | 0-800 MA | 340.00 |
| C-881 | 125-325 VDC | 0-800 MA | 315.00 |
| C-882 | 325-525 VDC | 0-800 MA | 360.00 |

[1]*For metered models add suffix "M" to model and add $30 to base price. (For example C-281M, $189.50.)*

**DC OUTPUT** (regulated for line and load):

Voltage ..... Refer to chart above.

[2]*Voltage range for any given model is completely covered in four continuously variable bands.*

Current ..... Refer to chart above.

[3]*Current rating applies over entire voltage range.*

Regulation (line) ..... Better than 0.15% or 0.3 Volt (whichever is greater). For input variations from 105-125 VAC.

Regulation (load) ..... Better than 0.25% or 0.5 Volt (whichever is greater). For load variations from 0 to full load.

Transient Response (line) ..... Output voltage is constant within regulation specifications for step-function line voltage change of plus (+) 10 volts or minus (−) 10 volts rms within the limits of 105-125 VAC.

Transient Response (load) ..... Output voltage is constant within regulation specifications for step-function load change from 0 to full load or full load to 0.

Internal Impedance .....
C-200 Series ..... Less than 6 ohms.
C-400 Series ..... Less than 3 ohms.
C-800 Series ..... Less than 1.5 ohms.

Ripple and Noise ..... Less than 3 millivolts rms.

Polarity ..... Either positive or negative may be grounded.

**AMBIENT TEMPERATURE AND DUTY CYCLE** ..... Continuous duty at full load up to 50°C (122°F) ambient.

**AC OUTPUT**
(unregulated) ..... 6.5 VAC (at 115 VAC Input).[4]
C-200 Series ..... 10 AMP.
C-400 Series ..... 15 AMP.
C-800 Series ..... 20 AMP.

[4]*Allows for voltage drop in connecting leads. Isolated and ungrounded.*

**AC INPUT** ..... 105-125 VAC, 50-400 CPS

**OVERLOAD PROTECTION:**
External Overload Protection ..... AC and DC fuses, front panel, with built-in blown-fuse indicators.
Internal Failure Protection ..... Fuse, rear of chassis.

**CONTROLS:**
DC Output Controls ..... Band-switches and screw-driver adjusting vernier-control, rear of chassis.
AC and DC Switches ..... Front panel.

*Prices and specifications effective November 1956, subject to change without notice.*

### GERMANIUM RECTIFIERS† · TRANSIENT-FREE OUTPUT · HERMETICALLY SEALED TRANSFORMERS

These new and compact power supplies occupy a minimum of space, deliver maximum performance. They are without qualification the finest power supplies in Lambda's long experience.

The 400 and 800 MA series include new, more efficient longer lasting germanium rectifiers. All *Com-Pak* models are constructed with hermetically sealed transformers and chokes. Completely protected from moisture, they can be depended on for long trouble-free service.

These new Lambda power supplies represent a major advance in thermal and mechanical design, and in outstanding performance. Send in your first order now for priority in handling.

***SEND FOR NEW CATALOG.** Complete specifications for all Lambda Power Supplies.*

†except in 200 MA series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**Electronics Corp.**
The First Name in Power Supplies
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COLLEGE POINT 56, N. Y.
Cable Address: Lambdatron, New York

## NEW PRODUCTS

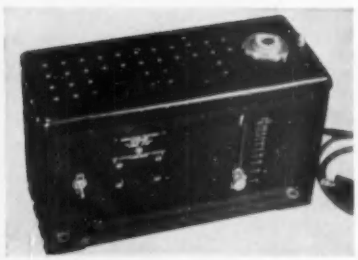
trols. Temperature of the analyzer is adjustable from 60 deg C to as high as 250 deg C and regulated to within 0.5 deg C.—Consolidated Electrodynamics Corp., Pasadena, Calif.

**Circle No. 13 on reply card**

### FUNCTIONAL DESIGN

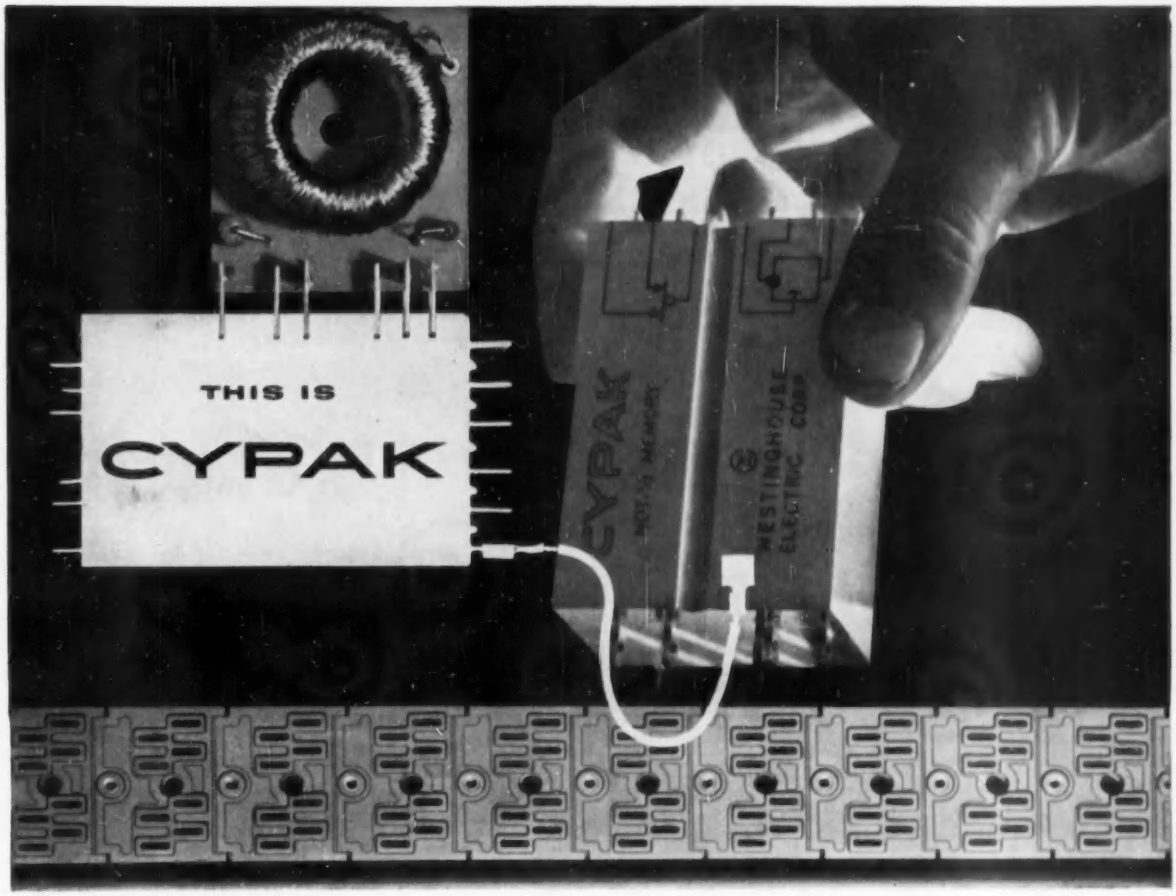
This brand new portable oscillograph incorporates many interesting features to achieve a trully functional design. The front panel is divided into visual and manual areas by means of an offset cast frame. New lettering styles and new control knobs are used. Knobs are arranged in basic "blocks of function" and sharp, contrasting colors simplify reading. The use of fall-away side panels reduces downtime for adjustments or replacements. High stability is achieved by an internal, self-regulating power transformer and an electronically regulated B+ and high voltage power supply. —Allen B. DuMont Laboratories, Inc., Clifton, N. J.

**Circle No. 14 on reply card**



### VIBRATION TESTER

The new vibration testing machine shown here features a rugged cast




# *for industrial control 15 times more reliable*

With CYPAK* control you can introduce a whole new concept of reliability for industrial systems. Unlike the mechanical relay, CYPAK has *no* moving parts. While twenty million open-close cycles is usually the maximum life of a mechanical relay, CYPAK systems can handle that many cycles in days, without a trace of fatigue. Down time due to wear, corrosion, or jamming no longer throws a block to expanding control system responsibility.

One reason for CYPAK dependability is Westinghouse Hipernik* V magnetic steel. In toroidal coils, this high-grade steel produces sharp current amplification to parallel the mechanical relay step function. These important magnetic characteristics are completely protected by sealing each CYPAK component panel in a solid plastic block.

Look into all the new opportunities in CYPAK by calling your Westinghouse sales engineer today. J-01003

*Trademark


Write today for your free copy of *The Whys and Wherefores of* CYPAK, Booklet B-6584. Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania.

**WATCH WESTINGHOUSE**

*WHERE THE FUTURE IS ALREADY IN PRODUCTION!*

## NEW PRODUCTS

aluminum base which houses the drive motor and variable-speed mechanism. Linear sinusoidal motion is imparted to the flexure mounted table through a connecting rod driven by a ball bearing mounted eccentric cam. A cone-type variable speed drive powered by a 1/15-hp split phase motor drives the cam. Frequency adjustment is provided on the front of the machine, amplitude setting at the top right side of the table. Important specs are as follows:

- frequency: infinitely variable, 10 to 55 cps.
- amplitude: infinitely variable, 0 to 0.040 in.
- test load: 5 lb maximum.

The Ahrendt Instrument Co., College Park, Md.

**Circle No. 15 on reply card**

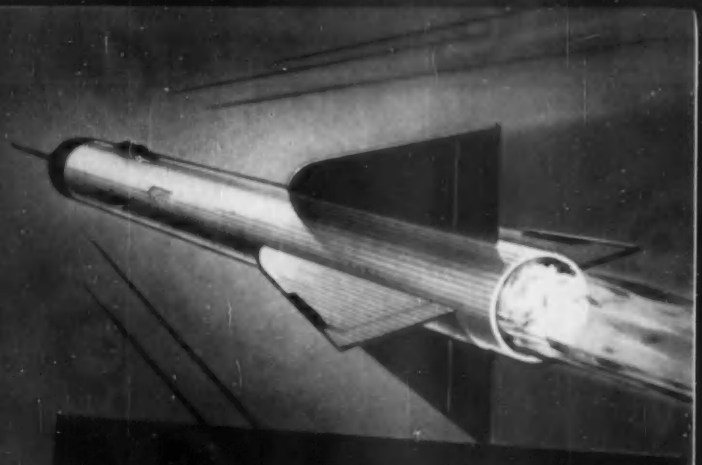
### PORTABLE PYROMETER

Equipped with nine interchangeable direct-reading scales, this potentiometer pyrometer is said to be the only single temperature testing unit that can be used with six types of thermocouples. It checks and calibrates any temperature instrument that operates in the range of 32 to 3,215 deg F and measures the dc potential of electrical equipment between 0 to 155 mv. The unit is accurate to within 0.16 percent of scale span. Its slidewire resolution exceeds 4,000 increments, and its effective open scale length is 50.5 in. Scales can be changed in 30 sec. No charts, graphs, or conversion tables are required. Completely self-contained, and with a built-in power supply, the pyrometer weighs only 14 lb.—Technical Associates, Inc., Indianapolis, Ind.

**Circle No. 16 on reply card**

*Now Available!*

# PHILCO Silicon Transistors



## With These Outstanding Advantages:

- Excellent performance at Temperatures from −60°C to +140°C
- Collector Saturation Voltage of 0.1 Volt or Under
- Maximum Frequency of Oscillation in the 15 Megacycle Range


Unmatched performance and reliability! Characteristics *assured* by extensive life tests under typical operating conditions. Philco PNP Silicon Transistors make practical *complete transisterization* of military and commercial circuits *—where high ambient temperatures are encountered.*

Philco Silicon Transistors are now in pilot production and immediately available for initial design work. Specify Type T-1025 for amplifier, oscillator and low level general purpose applications and Type T-1159 for high speed switching applications.

## FEATURES

**• HIGH TEMPERATURE PERFORMANCE • VERY LOW LEAKAGE CURRENT • HIGH SPEED • SUITABLE FOR DIRECT COUPLING • LOW SATURATION VOLTAGE • ABSOLUTE HERMETIC SEAL**

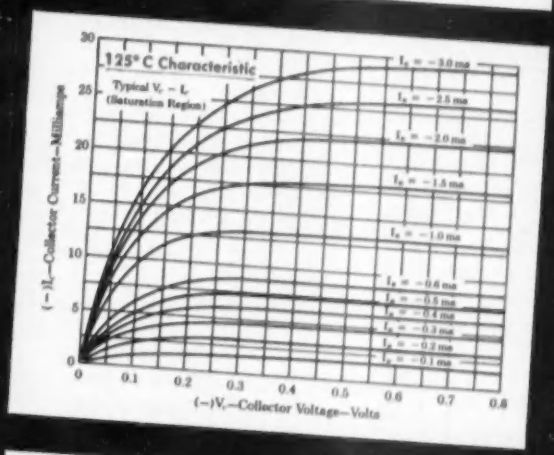
*Make Philco your prime source of information on Silicon Transistor Applications.*

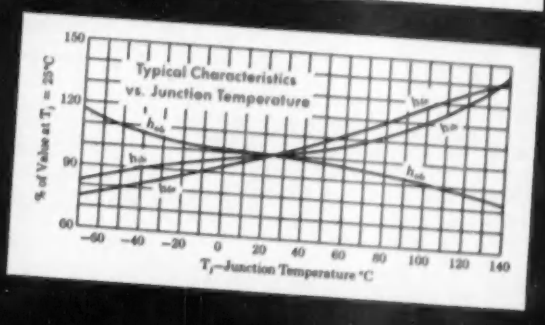
**Write to Dept. CE, Lansdale Tube Company Division, Lansdale, Penna.**

**Characteristics of Types T-1025 and T-1159**
($T_a$ = 25°C)

| Characteristic | Condition | Typical Value |
|---|---|---|
| Current Amplification Factor, $h_{fe}$ | $V_{cb} = -6$ v<br>$I_e = -1$ ma | 18 |
| Output Capacitance, $C_{ob}$ | $V_{cb} = -6$ v<br>$I_e = -1$ ma | 7 μμf |
| Maximum Oscillation Frequency, $f_{max.}$ | $V_c = -6$ v<br>$I_e = -1$ ma | 15 mc |
| Cutoff Current, $I_{cbo}$ or $I_{ceo}$ | $V_{cb}$ or $V_{ce} = -10$ v | .001 μa |

Maximum Power Dissipation—150 mw
Maximum Collector Voltage—T-1025-25 v
T-1159-10 v




# PHILCO CORPORATION

## LANSDALE TUBE COMPANY DIVISION

## LANSDALE, PENNSYLVANIA

## NEW PRODUCTS

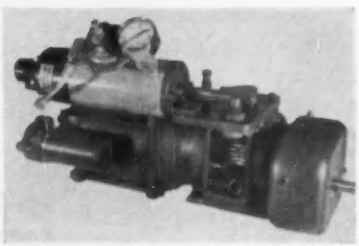
### SUB-SYSTEMS

**as seen at ISA show . . .**

**ROBOT-EYE**

Miniature photoelectric control components, featuring swivel-mounted light source and photocell units, are now available for installation in tight places. Cell unit uses a cadium sulfide cell for long life and high sensitivity. Control circuits, signal lights, and counter are housed in a heavy steel case which can be remotely installed. The units will follow 600 operations per minute and can work from direct beam, reflection from the passing object, or mirror reflection.—Standard Instrument Corp., New York, N. Y.

**Circle No. 17 on reply card**



**AIR CONTROL**

Shown is a ¼-hp variable speed drive unit with a pneumatic operator. The control operates on a 3-to-15-psi signal originating from liquid level, pressure, or flow rate devices, or from other transducers. The control signal can also be transmitted from a pneumatic recorder or controller. Normally, zero speed is obtained at 3 psi and maximum speed at 15 psi. However, other speed combinations can be arranged. Transmissions have a variety of built-in reducers, including spur and worm types. They are sold with or without built-in motors. Larger units are available up to 3 hp.—Graham Transmissions, Inc., Menomonee Falls, Wis.

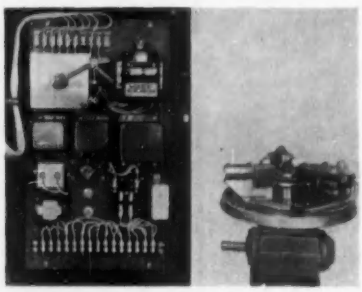
**Circle No. 18 on reply card**

## NEW PRODUCTS

### GIANT SPECTROMETER

The photo above shows a ⅓-size scale model of a new giant spectrometer. This system is capable of analyzing and indicating the percent concentration of as many as 18 elements in a metal in less than 60 sec. These 18 may be selected from 60 different elements which the direct reader is capable of measuring. On the left in the photo is the direct reading optical and electronic unit; at the right, the indicator console. The miniature scale model should enable engineers to become familiar with the appearance and general operation of the instrument.—Baird Associates, Atomic Instruments Co., Cambridge, Mass.

**Circle No. 19 on reply card**



### DELAYED CONTROL

This unique magnetic memory system is especially designed for delayed control of high-speed continuous process lines and automatic sorting of items moving through complex conveyor systems. In a typical application, an error or defect signal magnetizes a sector of a steel disc in the memory unit. The disc rotates in synchronism with the processing or conveyor line. Measurements are read off the disc at the time the defective material reaches the action or sorting point. Readout is totally independent of line speed. After readout, the disc is erased and

**Circle No. 21 on reply card**

## NEW PRODUCTS

ready for reuse. One system will accommodate one or two sorting stations. Each system consists of a control unit and a memory unit as shown above.—Automation, Inc., Wellesley Hills, Mass.

**Circle No. 20 on reply card**

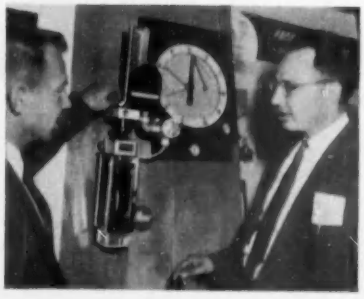
### CONTROL UNIT

A new proximity transducer system utilizes the principle employed in military mine detectors to sense the presence of metal objects without direct contact. The instrument will sense metal objects up to ¾ in away through such nonmetallic substances as plaster, paper, pasteboard, or wood at rates up to 1,000 units per second. Two systems are available: a "B" system used primarily with electronic equipment, and an "RB" system containing an SPDT mercury relay for controlling electrical machinery. Counting operations, motor or valve control, and the actuation of warning devices are a few of its applications.—Electro Products Laboratories, Chicago, Ill.

**Circle No. 21 on reply card**

## MEASUREMENT & DATA TRANSMISSION

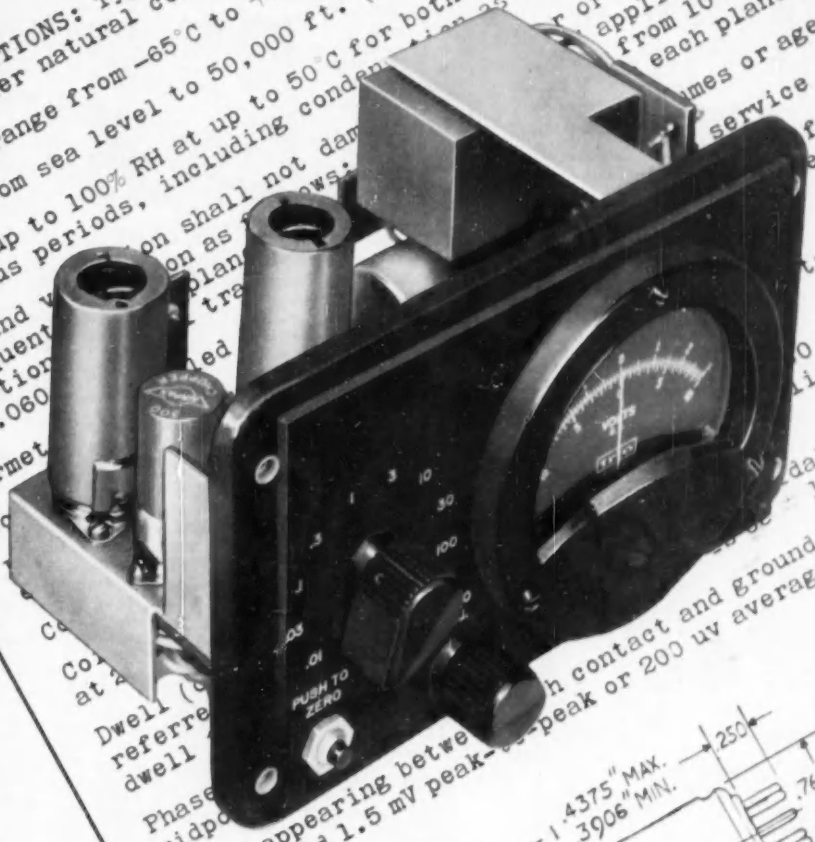
**as seen at ISA show . . .**

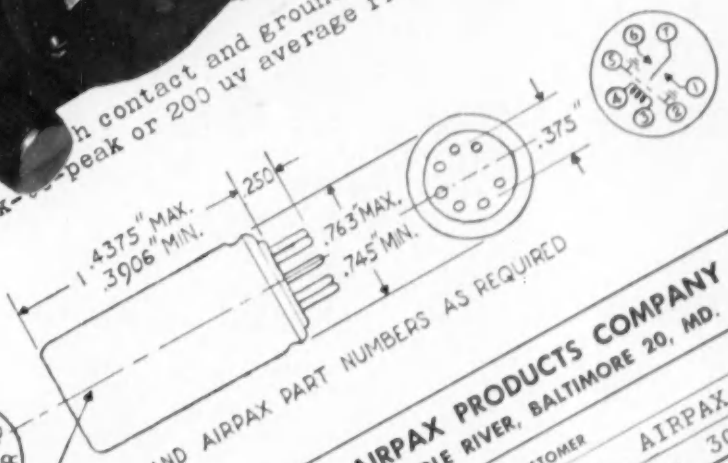


### NEW FLOW TRANSMITTERS

Two new flow transmitters, an electrical model shown here and a pneumatic model not shown, feature complete interchangeability. Both have the same rotameter extension unit and the same interchangeable armature unit. On the electrical transmitter, the armature movement

# Miniature DC VTVM uses AIRPAX chopper





## RATING ON TYPE 300 CHOPPER

Drive: 6.3 volts at 400 CPS
Contacts: up to 100 volts at 2 ma
Dwell Time: 147 electrical degrees
Phase Angle: 65 electrical degrees lagging
Noise: 200 microvolts average across a 1 megohm resistance into a band from 20 CPS to 50 KC from each contact to ground

Hermetically sealed for maximum life under all ambient conditions. Available to plug into a 7-pin miniature tube socket, or with solder lugs and flange mount.

AIRPAX
DESIGNERS ENGINEERS

MIDDLE RIVER BALTIMORE 20, MD.

## Zero Drift Is 0.5% Maximum

An Airpax Type 300 chopper gives this panel-mounting instrument several unusual characteristics. It has a 5-megohm input impedance, yet only 0.5% maximum drift. With it you can read as low as 500 DC microvolts and as high as 300 DC volts, both to an accuracy of 2%.

You may have another equipment that can benefit from a chopper to convert DC to AC. Why not discuss your problem with us today? Airpax makes the chopper (Trio Laboratories, Seaford, New York makes the VTVM).

## NEW PRODUCTS

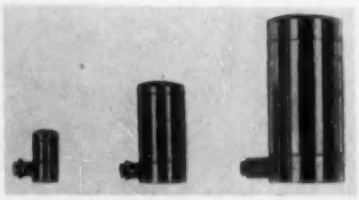
varies the force on a strain gage element; this same motion in the pneumatic model initiates a force-balance loop. The pneumatic transmitter is available with or without 10 percent drop-out bellows which might be desirable where flow is to be integrated. This drop-out features plug-in construction, and can be removed at any time should requirements change. Gage on the pneumatic model indicates output pressure and percent of scale.—Brooks Rotameter Co., Lansdale, Pa.

**Circle No. 22 on reply card**

### CAT'S EYE CELL

This compact photoelectric control is available for a wide variety of applications. A few of the operations to which it could be applied are counting, sorting, color matching, level detection, and edge registration. The unique cat's eye receiver and efficient optical system permits close control of machine position. The slit can be rotated to any desired position, and lends itself to readout with a suitable optical shaft position indicator.—Mason Instrument Co., Mount Vernon, N. Y.

**Circle No. 23 on reply card**

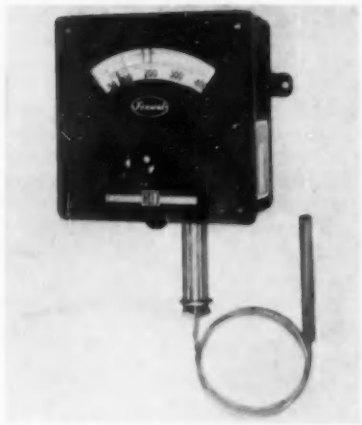


### ACCELEROMETERS

Available in three models, these new standard accelerometers are well suited for vibration measurements over a wide frequency range of operation. The units will reveal high order harmonic components of vibration, and

can be used in making measurements for noise reduction problems. There is no phase shift between applied acceleration and generated output voltage and the units are sensitive only to the vector component of acceleration lying along their axes. For constant velocity of vibration, output is directly proportional to frequency, and for constant displacement it is proportional to the square of the frequency. Dynamic ranges are from 0.001 to 500, 1,000, or 2,000 g; frequency ranges from 10 to 15,000, 30,000, or 80,000 cps.—Massa Laboratories, Inc., Hingham, Mass.

**Circle No. 24 on reply card**



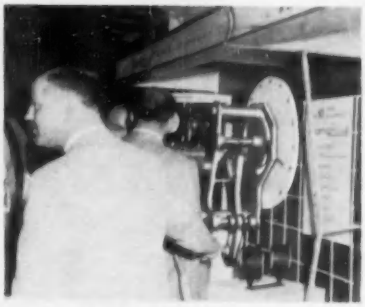
### CHOICE OF ELEMENTS

A series of indicating temperature controllers built around interchangeable elements is now available. Units offer high accuracy and rugged construction. The wide choice of interchangeable elements permits the user to tailor the control to the application. Each major element—i.e., switching and indicating mechanism, switch type, temperature range, housing, bulb diameter, and capillary length—is available in at least several variations or ratings. Features common to all models are: set-points easily adjusted by means of knobs on the front panel, bulb temperature indicated on the lower half of the dial, units case-compensated for ambient temperatures between 50 and 150 deg F, and easy access for adjustment and service in the field.—Fenwal Inc., Ashland, Mass.

**Circle No. 25 on reply card**

## NEW PRODUCTS

as seen at ISA show . . .



### GAGE MOVEMENT

A pressure gage is now available which incorporates a patented gearless movement. Rack, pinion, and hairspring assembly are eliminated. The new movement uses a long deflection constant force spring. Motion of the sector is transmitted to the pinion through this spring. Sector rotation is converted to responsive pointer rotation in a ratio of pinion radius to sector radius. The gage is said to offer exceptionally long life in pulsating systems where the amplitude indicated by the pointer is under 30 deg of full scale.—Norden-Ketay Corp., New York, N. Y.

**Circle No. 26 on reply card**


### FORCE TRANSDUCERS

Combining the proving ring and differential transformer principles, these new force transducers provide an output emf that is precisely proportional to applied force, and have excellent stability of calibration. The

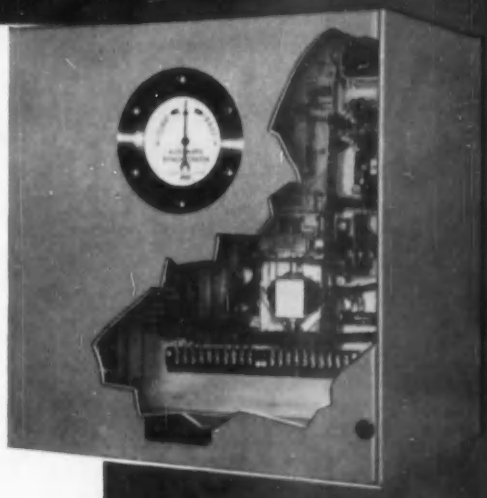
# another example of precision synchronization . . . by VICKERS

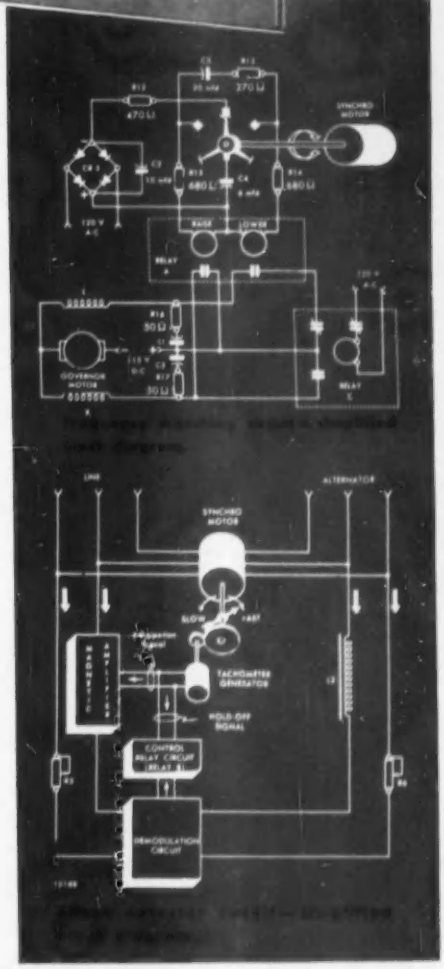
## PRECISE SYNCHRONIZATION OF AUXILIARY ALTERNATOR WITH POWER DISTRIBUTION LINE

assured with the

# VICKERS*

## AUTOMATIC ALTERNATOR SYNCHRONIZER





A leading manufacturer of diesel-driven auxiliary power generating equipment achieves precise synchronization of the alternator with the main power line when paralleling with the use of Vickers Automatic Alternator Synchronizers.

The Vickers synchronizer automatically

- Matches the frequency of the alternator to that of the main power line to within 1/5 cycle per second by controlling the diesel governor.
- Closes the circuit breaker which parallels the alternator with the line at the instant of phase synchronization by means of a phase detector and anticipation circuit.

Free of vacuum tubes, and with a minimum of moving parts, Vickers automatic synchronizers utilize static magnetic amplifiers for trouble-free performance under adverse conditions with little or no maintenance.

■ ■ ■

Some of the Many Other Applications for Vickers Automatic Synchronizers

AIRCRAFT PROPELLERS

CONVEYORS

TRANSFER MACHINES

**Vickers control engineers will work with you in solving *your* synchronization problems.**

*TRADEMARK

VICKERS ELECTRIC DIVISION

VICKERS INCORPORATED a unit of Sperry Rand Corporation

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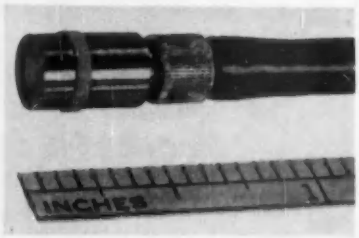
## NEW PRODUCTS

units are available in ranges from plus or minus 10 lb to plus or minus 100,000 lb and are accurate to within 0.5 percent of these ranges. Excitation frequency range is 60 to 10,000 cps. Maximum sensitivity is 40 mv per volt at rated load. A mechanical zero adjustment is provided to null tare loads if desired.—Daytronic Corp., Dayton, O.

**Circle No. 27 on reply card**




### PRESSURE TRANSDUCERS

This miniature, high-precision pressure transducer is one of four models now available. Measuring only ¼ in. in diam by ½ in. long, the units are said to exhibit superior characteristics. Response time is in the order of 1 microsec. Signals are exceptionally sharp and free from electrical and mechanical noise. It is claimed that measurements as low as 0.01 psi have been made successfully on shock tubes. The units will measure not only steady and slowly varying pressures, but also fast pressure transients. Simple conventional static methods are used for calibration. The available models are the blast gage, shock tube gage, ballistics gage, and the hyper-ballistics gage.—Kistler Instrument Co., North Tonawanda, N. Y.

**Circle No. 28 on reply card**

## INFORMATION DISPLAY INSTRUMENTS

### WETTED RELAYS

A series of three new digital voltmeters are designed especially for applications demanding continuous operation. The use of mercury wetted contact relays is said to assure a life expectancy of more than 1 billion

Transitron

# SILICON VOLTAGE REGULATORS

**UP TO 50 ma**

| Type | Voltage Range (volts) | Maximum Average Current ma at 25°C | Maximum Average Current ma at 125°C | Maximum Dynamic Resistance (ohms) |
|---|---|---|---|---|
| SV-5 | 4.3 - 5.4 | 50 | 10 | 55 |
| SV-6 | 5.2 - 6.4 | 40 | 8 | 20 |
| SV-7 | 6.2 - 8.0 | 30 | 6 | 10 |
| SV-9 | 7.5 - 10.0 | 25 | 5 | 20 |
| SV-11 | 9.0 - 12.0 | 20 | 4 | 70 |
| SV-13 | 11.0 - 14.5 | 17 | 3.4 | 100 |
| SV-15 | 13.5 - 18.0 | 14 | 2.8 | 120 |
| SV-18 | 17.0 - 21.0 | 12 | 2.4 | 200 |

**UP TO 150 ma**

| Type | Voltage Range (volts) | Maximum Average Current ma at 25°C | Maximum Average Current ma at 125°C | Maximum Dynamic Resistance (ohms) |
|---|---|---|---|---|
| SV-804 | 4.3 - 5.4 | 150 | 30 | 55 |
| SV-805 | 5.2 - 6.4 | 120 | 24 | 20 |
| SV-806 | 6.2 - 8.0 | 90 | 18 | 10 |
| SV-808 | 7.5 - 10.0 | 75 | 15 | 20 |
| SV-810 | 9.0 - 12.0 | 60 | 12 | 70 |
| SV-812 | 11.0 - 14.5 | 50 | 10 | 100 |
| SV-815 | 13.5 - 18.0 | 40 | 8 | 120 |
| SV-818 | 17.0 - 21.0 | 35 | 7 | 200 |

**UP TO 2 AMPS**

| Type | Voltage Range (volts) | Maximum Average Current (amps) at 25°C | Maximum Average Current (ma) at 125°C | Maximum Dynamic Resistance (ohms) |
|---|---|---|---|---|
| SV-904 | 4.3 - 5.4 | 2.0 | 400 | 2 |
| SV-905 | 5.2 - 6.4 | 1.6 | 320 | 2 |
| SV-906 | 6.2 - 8.0 | 1.2 | 240 | 2 |
| SV-908 | 7.5 - 10.0 | 1.0 | 200 | 2 |
| SV-910 | 9.0 - 12.0 | .8 | 160 | 2 |
| SV-912 | 11.0 - 14.5 | .7 | 140 | 4 |
| SV-915 | 13.5 - 18.0 | .6 | 120 | 6 |
| SV-918 | 17.0 - 21.0 | .5 | 100 | 8 |

**Transitron's** silicon voltage regulators (sometimes called Zener diodes) are constant voltage elements for control and similiar circuitry. They provide excellent regulation and stability over a wide operating range.

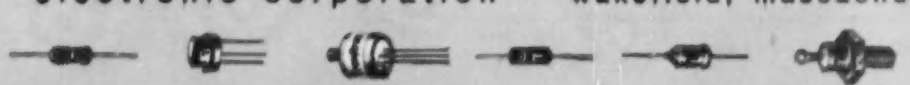
Through improved thermal design, each of the three regulator series will give high load currents in the smallest possible size. The subminiature glass types, for example, provide twice the current in less than half the size of conventional regulators. High power types can be used to simplify circuits and eliminate amplification stages.

Inquiries are invited on higher voltage regulators, and precision, temperature compensated voltage reference elements.

**SEND FOR BULLETIN TE 1352**

Transitron

electronic corporation • wakefield, massachusetts



Germanium Diodes | Transistors | Silicon Diodes | Silicon Rectifiers

## NEW PRODUCTS

accurate readings from these instruments. Switches are hermetically sealed, and platinum contacts are wetted with mercury by capillary connection to a mercury reservoir. The five-digit model has a range of 00.000 to plus or minus 99.999 volts dc with resolution of 0.001 volt, and plus or minus 100.00 to plus or minus 999.99 vdc with resolutions of 0.01 volt. Units give three complete readings per second with automatic polarity indication.—Non-Linear Systems, Inc., Del Mar, Calif.

**Circle No. 29 on reply card**

**as seen at ISA show . . .**

### LIQUID LEVEL

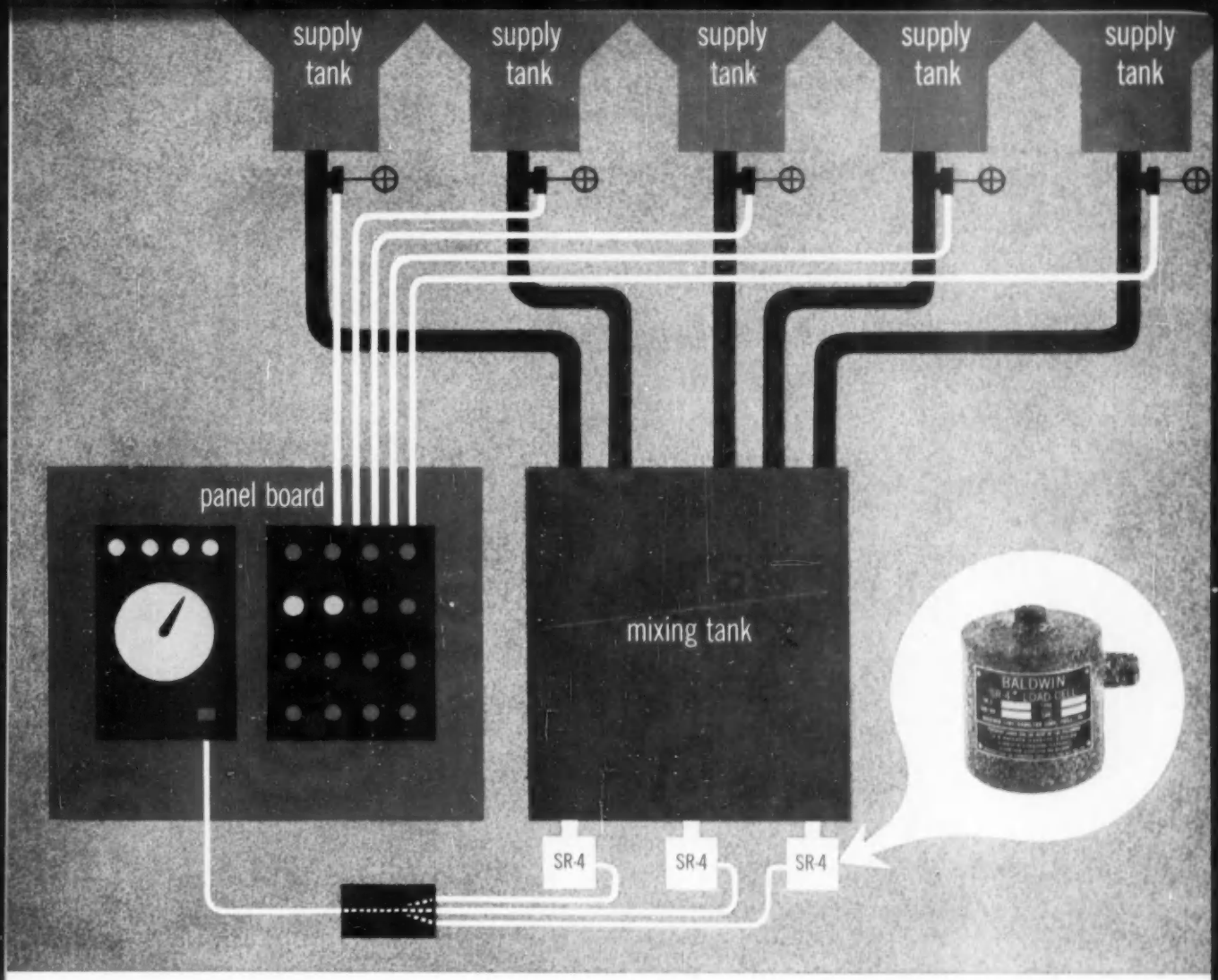
This new displacement-type liquid level controller eliminates bearings and knife edges by introducing a torque table. The face of this table drives a torque tube which is free to twist under the action of a displacer. Since there is no dependence on sharp edges, performance is essentially constant and normal process residues do not hamper operation. Units are available with external displacer chambers or in models for direct displacer immersion in the process vessel. Control action is interchangeable for proportional or differential gap response; proportional band is 1 to 150 percent, with automatic reset optional.—Kieley & Mueller Inc., Middletown, N. Y.

**Circle No. 30 on reply card**

### HIGH-SPEED RECORDER

An automatically-sequenced, high-speed digital recorder handles on or off voltage phenomena appearing on 45 channels at sampling rates as high as 2,500 per sec. Typical applications include monitoring of operations and

Germanium Diodes Transistors Silicon Diodes Silicon Rectifiers




# Baldwin electronic SR-4® system controls chemical process to ±¼% accuracy

Closed loop control of this chemical plant's mixing process is provided by an integrated Baldwin SR-4 system with a maximum degree of accuracy and repeatability.

To add the correct amount of each ingredient, the Baldwin indicator controller automatically opens and closes supply tank valves. The controller receives its signals from three Baldwin SR-4 transducers which weigh each ingredient as it is added to the batch. Load cells install conveniently just below the mixing tank. Baldwin load cells are instantaneously responsive, have no moving parts, require no maintenance. The mixer is timer actuated. Lights on the panel board show cycle stage at all times.

You can have a Baldwin SR-4 electronic control system, specifically designed for your requirements, for any application involving weight, pressure, tension, torque or thrust. We engineer the entire system and calibrate it as a unit, to guarantee you maximum accuracy. For your copy of our general bulletin 4300, write Dept. 3252, Electronics & Instrumentation Division, BLH Corporation, Waltham, Massachusetts.

**SEE OUR EXHIBIT AT THE AUTOMATION SHOW**

BALDWIN BLH LIMA-HAMILTON

***ELECTRONICS & INSTRUMENTATION DIVISION***

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## NEW PRODUCTS

data in digital computers and other data processing systems. Paper speed is over 150 in./sec, allowing a ¼-in. spacing for the maximum sampling rate. A three-sequence digital interval generator is used to program paper drive functions.—Potter Instrument Co., Great Neck, N. Y.

**Circle No. 31 on reply card**

**as seen at ISA show . . .**

### MULTI-POINT TRC

The instrument being demonstrated in the above photo is one of a series just released by the manufacturer. Its function is to continuously record temperatures at 24 remote points and to take control action on the highest temperature recorded. Each couple is assigned a number, and as each is measured its number is printed on the strip chart. Seven chart speeds, from 1 to 30 in. per hour, are available. The dc potentiometer circuit is automatically standardized every 48 min.—Leeds & Northrup Co., Philadelphia, Pa.

**Circle No. 32 on reply card**

### ON-OFF CONTROLLER

Either on-off or locking control action may be selected on this instrument. With on-off, the device takes con-

## IMPORTANT DEVELOPMENTS AT JPL

## Pioneers in Guidance Systems

*The Jet Propulsion Laboratory is a stable research and development center located to the north of Pasadena in the foothills of the San Gabriel mountains. Covering an area of 80 acres and employing 1550 people, it is close to attractive residential areas.*

*The Laboratory is staffed by the California Institute of Technology and develops its many projects in basic research under contract with the U. S. Gov't.*

*Qualified personnel employment inquiries now invited.*

For many years the Jet Propulsion Laboratory has pioneered in the design and development of highly accurate missile guidance systems, utilizing the most advanced types of gyroscopes, accelerometers and other precision electro-mechanical devices. These supply the reference information necessary to achieve the hitherto unattainable target accuracies sought today.

The eminent success of the early "Corporal" missile flights shortly after World War II firmly established the Laboratory as a leader in the field of missile guidance. These flights also initiated experiments involving both inertial and radio-command systems employing new concepts of radar communication. Because of this research and experimentation JPL has been able to add materially to the fund of knowledge available to designers of complex missile systems.

This development activity is supported by basic research in all phases of electronics, including microwaves and antennas, new circuit elements, communications and reliability in addition to other branches of science necessary to maintain a fully integrated missile research organization.

The Jet Propulsion Laboratory, therefore, provides many challenging opportunities to creative engineers wishing to actively apply their abilities to the vital technical problems that require immediate and future solution.

We want to hear from men of proven ability. If you are interested please send us your qualifications now.

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MECHANICAL ENGINEERING

**JET PROPULSION LABORATORY**

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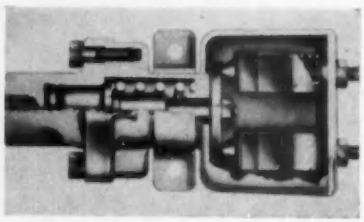
## NEW PRODUCTS

trol action when the signal reaches the preset limit, but continues to test the signal periodically. If a permissible signal level is reached, the unit stops its control of auxiliary equipment but continues to indicate the signal. With locking control, the device must be reset manually each time the signal reaches the control point. Included among the functions that can be controlled by the instrument are voltage, current, torque, pressure, temperature, liquid level, speed, depth, sound, and deflection. Control accuracy is held within 2 percent of dial settings.–Tipp Mfg., Co., Tipp City, Ohio.

**Circle No. 33 on reply card**

## CONTROL DEVICES



### RUGGED PRESSURE SWITCH

The new pressure switch shown here is capable of sensing two different pressures in one system and actuating independent electrical circuits at any two points. Depending on its setting, the switch will sense accurately any system pressure over an adjustable range of 15 to 3,000 psi for proof pressures of 3,000 to 7,000 psi. It incorporates two spdt snap-acting switches rated for ac and dc circuits. Pressure settings are made by two external adjustment screws that can be locked in place. One model has calibrated dials that permit visual setting of the switch, without the use of gages.—Barksdale Valves, Los Angeles, Calif.

**Circle No. 34 on reply card**

### SPEED ADJUSTER

This manufacturer's standard line of variable-speed torque converters is now available with an optional screw adjustment. The new adjusting device is also available in kit form for

INTRODUCING...

*the first combined*

# GPC AND DDA

GENERAL PURPOSE DIGITAL COMPUTER AND DIGITAL DIFFERENTIAL ANALYZER

***ultimate versatility in solving complex technical problems...***

The general purpose digital computer solves most scientific and engineering problems with speed and accuracy... yet easier programming makes the digital differential analyzer a superior choice for solving differential equations. Bendix now combines the advantages of both in the *new* G-15D Computer and its optional DDA accessory. Working together, and supported by a full complement of input-output equipment, these units provide the *best* means of solution. And the rental or purchase cost is far below that of most general purpose computers alone.

*A new brochure tells the details of the G-15D's talent for conserving your scarce engineering manhours. Let us send you a copy.*

Bendix Computer

DIVISION OF BENDIX AVIATION CORPORATION

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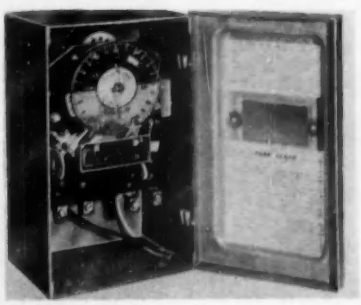
## NEW PRODUCTS

field installation on units now in service. Addition to the screw adjustment is said to permit several types of remote control. Fifty revolutions of the screw cover the full speed range, making calibration and fine adjustments possible. Unit is said to be undisturbed by vibration.—Revco, Inc., Minneapolis, Minn.

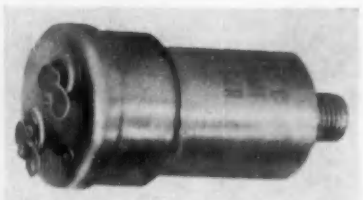
**Circle No. 35 on reply card**



### SKIP-A-DAY

The timer shown here combines two controls in one unit. The manufacturer's astronomical dial will turn lights on at sunset every day. It turns them off at sunrise automatically, but may also be set to turn them off at a preset hour. This control is said to be accurate to within 2 min of the sun's ever-changing schedule. The second control in the unit is the skip-a-day wheel, which makes it possible to limit lighting to as many nights per week as desired. The wheel is a seven-armed control, and the insertion of a set screw in any arm prevents closing of the lighting circuit on a particular night.—Tork Clock Co., Mount Vernon, N. Y.

**Circle No. 36 on reply card**



### PRESSURE SWITCH

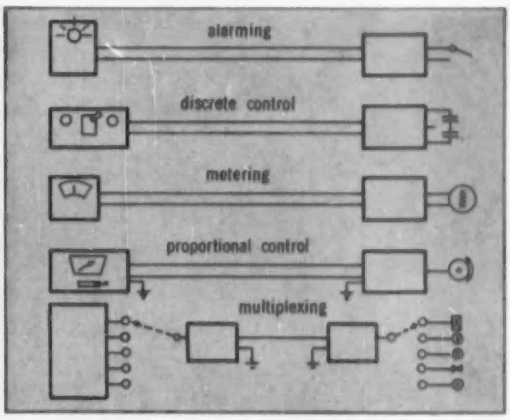
These subminiature absolute air pressure switches are available in nine models. They feature a wide temperature range and stability under severe shock and vibration conditions.

# how to simplify

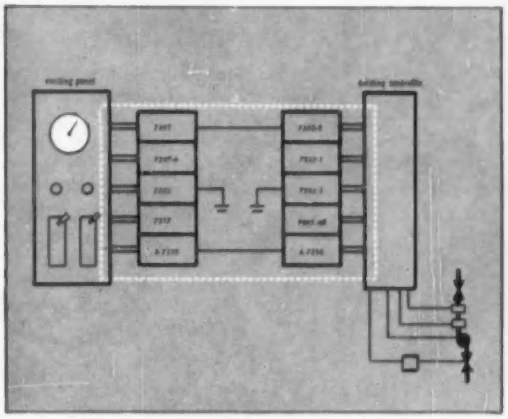
# *REMOTE CONTROL SOLUTIONS*

**STANDARD PLUG-IN MODULES** now available from Sparton feature time-proven communication concepts in flexible control "building blocks".

These "off-the-shelf" modules enable positive remote supervision and control—for almost any problem—without excessive special engineering or construction cost.




**5 BASIC SYSTEMS** are available from Sparton: alarming (polarized d.c. pulses, tone, circuit make-break); discrete control and supervision (polarized d.c. pulses, tone, time-coding, pulse-time coding); metering (both digital and analog data); proportional control (polarized d.c. signals, tone, d.c. pulses, continuous d.c. signals); channel multiplexing (flip-flop, time-sharing, multiplexed tones).



**COMBINE WITH EXISTING CONTROLS** for a tailor-made solution to your needs. System blocked here, for instance, uses 10 modules to provide remote pump start/stop, power failure and order disagreement alarm, pressure interlock, remote throttling, and remote flow metering. Ties into existing panel at master end and existing controller at slave end.

**COMPLETE CONTROL CENTERS** for remote supervision and control of any process, automated production line, substation or what-have-you are engineered and installed by Sparton, utilizing Sparton modules, plus transducers, metering and control devices supplied to strict specifications. Sparton assumes full responsibility for the integrated system.

***This data may help solve your problems. Check brochures you wish and return.***

Sparton

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- ☐ Metering
- ☐ Proportioning Control
- ☐ Channel Multiplexing
- ☐ Waterworks Applications
- ☐ Petrochemical Applications
- ☐ General Industrial Applications

**SPARTON CONTROL SYSTEMS DIVISION**
**The Sparks-Withington Company**
Jackson, Michigan

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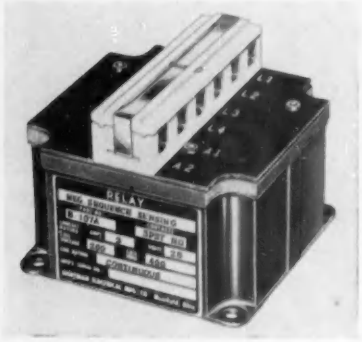
## NEW PRODUCTS

Units can be applied to the electrical control of equipment or to the operation of signal lights or alarms, in response to pressure limits. Electrical terminals are through glass to metal hermetic seals. Accuracy of the switches is within 0.5 psi, and maximum overload is 45 psia.—Newark Controls Co., Bloomfield, N. J.

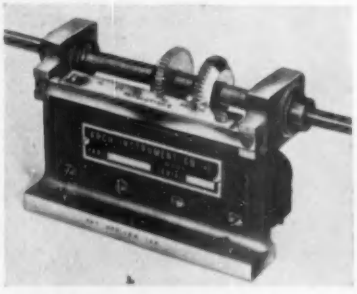
**Circle No. 37 on reply card**



### WATCHMAN

Employing all static components, this negative sequence sensing relay is designed to protect 115/200-volt, three-phase, 400-cycle power systems. Sensitive to phase unbalances of as little as 5 negative sequence volts, the unit closes a 3-amp output circuit when the unbalance is detected. An inverse time delay is provided to prevent nuisance tripping. Units weigh only 23 oz.—Hartman Electrical Mfg., Co., Mansfield, Ohio.

**Circle No. 38 on reply card**



### ACCURATE LIMITS

This new unit provides accurate limitation of rotary motion by means of two cams driven along a lead screw. The cams actuate two spdt snap-act-

*The Memo-Scope, incorporating the famous* MEMOTRON, *combines the unique quality of information persistence with all the features of a superior quality laboratory oscilloscope.*

*The Memo-Scope by Hughes is a storage oscilloscope that captures and retains any number of traces indefinitely at a constant intensity until intentionally erased. Traces are readily visible in a brightly-lighted room, and may be easily photographed.*

NEW!

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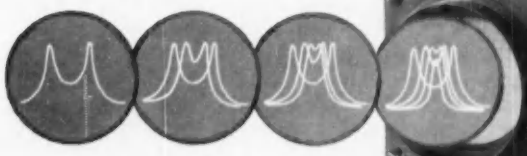

MEMO-SCOPE

Memo-Scope is available in two models: Portable (Model 103), and Rack Mounted (Model 103-R).

Plug-in vertical amplifiers of a variety of characteristics are available to increase flexibility. Hinged camera mount swings photographic apparatus aside for direct-display view.

**TYPICAL APPLICATIONS**

Study of transient electrical phenomena as short as 10 microseconds in duration.

Presentation of tube or transistor characteristics without the necessity of repetition.

Display of frequency response curves without the need of a sweep generator.

Spectrum analyses.

Shock testing.

Electrocardiographic studies.

Detection and measurement of relay bounce or contact noise.

High-speed X-Y plotting.

Investigation of transient behavior of power supply regulation.

Camera shutter timing.

**CONDENSED SPECIFICATIONS**

5-INCH MEMOTRON STORAGE TUBE

Erasure: internal waveform generator triggered by a push button or by application of a 25-volt, 1-millisecond positive external pulse, erases stored traces within 250 milliseconds.

DC Blanking: CRT grid direct coupled to external or internal blanking gate allows beam to be turned off except during sweep and insures constant sweep-time intensity.

Deflection Plates: available at rear terminal strip for direct connection.

AMPLIFIERS

Frequency Response: DC to 250 kilocycles within 10%.

Rise Time: 2 microseconds.

TRIGGERED LINEAR SWEEP

Range: 10 μsec to 10 seconds per division, adjustable continuously or in 18 calibrated steps.

Trigger: vertical amplifier signal, AC line or external pulse, either polarity, DC or AC coupled. Minimum external trigger amplitude, 0.1 volts.

Ready Light: neon lamp indicates sweep is at left side of screen, ready for trigger.

AMPLITUDE CALIBRATOR

Available at front panel terminal—one kilocycle square wave with peak-to-peak amplitude of 0.01, 0.1, 1.0 or 10 volts, within 3%.

BEAM POSITION INDICATORS

Four neon lamps show position of writing beam when not on screen.

ILLUMINATED GRATICULE

Illuminated scale calibrated in 1/3" squares in 10 × 10 array.

RACK MOUNTING

Model 103-R available on standard 14" × 19" relay rack panel.

DIMENSIONS

13" wide, 14" high, 20" deep. Etched circuit epon glass electrical chassis.

*For additional information on Memo-Scope*

**HUGHES PRODUCTS**

A DIVISION OF THE HUGHES AIRCRAFT COMPANY

*write to:* HUGHES PRODUCTS · ELECTRON TUBE
*International Airport Station, Los Angeles 45, California*

## NEW PRODUCTS

ing switches mounted beneath the lead screw. Suitable gearing connects the lead screw to the system being controlled. The unit is said to have an adjustability of 1 part in 3,400, and a repeatability of plus or minus 5 min of arc per revolution. Limit of travel for the cams is from 1 to 70 turns of the lead screw.–Arch Instrument Co., Inc., North Quincy, Mass.

**Circle No. 39 on reply card**


### TIME DELAY

The new dial head AGASTAT time delay relay shown above was designed specifically for those applications requiring frequent time adjustments. Dial markings permit easy calibration for accurate adjustment, and each dial is color coded to identify the timing range. Four individual timing ranges are available. Complete adjustment is attained within each range by one complete turn of the dial. Other elements of the relay, such as the pneumatic timing head, solenoid assembly, switch, coil, and terminals, are the same as in previous models.–Elastic Stop Nut Corp. of America, Elizabeth, N. J.

**Circle No. 40 on reply card**

### COMPACT RELAY

For applications where compactness and light weight are essential, or where external electromagnetic effects must be held to a minimum, this new relay should prove quite suitable. Housed in a tinned brass case, hermetically sealed, it is supplied for miniature seven-pin socket operation or with curved terminals for solder

# WEATHERHEAD

## First in components for HYDRAULIC SYSTEMS

Look at anything . . . anywhere in the world . . . in hydraulics, diesel power or machine tool applications . . . equipment for instrumentation, oil drilling, mining, road building, petro-chemicals or even atomic power . . . chances are the vital air and fluid lifelines are secured with WEATHERHEAD.

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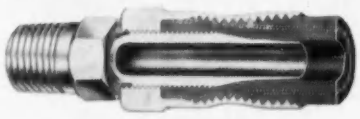
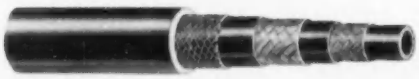
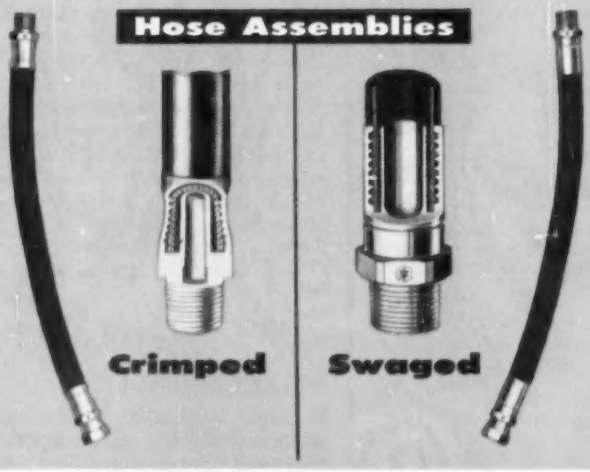


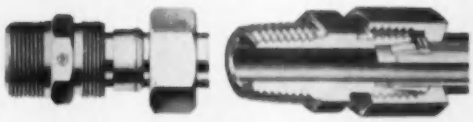
**Bulk Hose**



**Hose Assemblies**




**ERMETO**



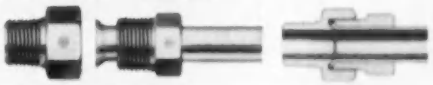
**SAE 37° FLARE**

3-PIECE

2-PIECE

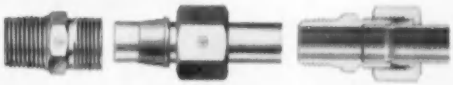
**SAE 45° FLARE**

**INVERTED FLARE**



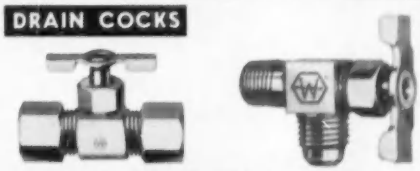
**COMPRESSION**

**SELFALIGN**



**PIPE**

**DRAIN COCKS**



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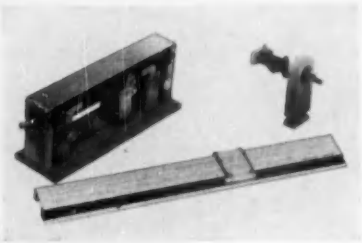
## NEW PRODUCTS

connection. Nonmagnetic contacts carry 35 ma at 6 vdc noninductive; loads up to 0.5 amp at 28 vdc noninductive can be handled depending on the moving coil sensitivity and number of operations.—Weston Electrical Instruments Corp., Newark, N. J.

**Circle No. 41 on reply card**



### LIMIT STOPS

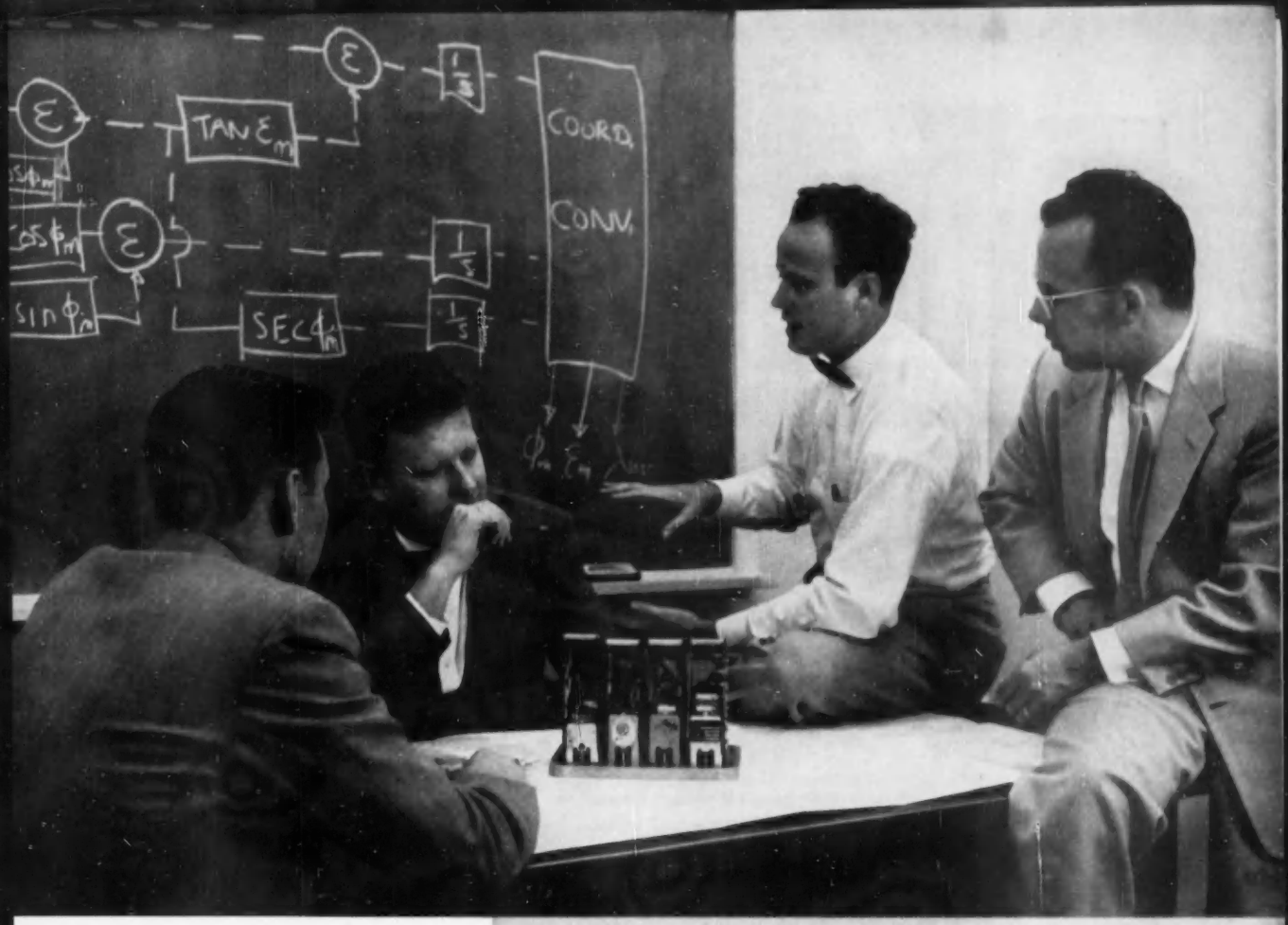
Three new types of limit stops are now available for the control of shaft rotation. The wafer limit stop is used where the load is comparatively light and the number of turns is few. Limits are set by the number of angular wafers placed on a shaft, each wafer permitting 300 deg of rotation. Maximum rotation is about 17 turns. The lead screw mechanical stop is designed for more turns and heavier loads. Each inch of separation between stops permits 32 turns. Maximum turns are 60, 120, and 180. Where torque or inertia is high, the lead screw electromechanical stop can be used. This unit, which permits 1 to 100 turns, includes a limit switch to cut off power before its limit is reached.—Servo Corp. of America, New Hyde Park, N. Y.

**Circle No. 42 on reply card**

### ROTARY SWITCH

Featuring solid silver alloy contacts, rotors, and slip rings, this new series of rotary switches can carry up to 15 amps and break 1 amp noninductive. Each switch has three poles and can be ordered with up to nine positions per hole with shorting type action or five positions per pole with nonshorting type action. Physical dimensions are 1¾ in. in diam by 1⅛ in. long.—The Daven Co., Livingston, N. J.

**Circle No. 43 on reply card**




G. D. Schott (second from left), Flight Controls Dept. Head, discusses new techniques in the mechanization of autopilots with R. D. Wertz (left), Flight Controls Research Engineer; R. J. Niewald, Flight Controls Analysis Section Head; and B. C. Axley, Servomechanisms Analysis Group Engineer.

# MISSILE SYSTEMS FLIGHT CONTROLS

One of the most critical problems encountered in the development of a successful missile system involves attaining rapid responses of controls *consistent with system stability*. Moreover, it is a problem of increasing importance as new aerodynamic configurations require major advances in flight controls performance.

At Lockheed, Flight Controls engineers are developing unique control methods to cope with this growing problem. Their expanded activities have created new positions for those possessing experience and a high order of ability in:

- Hydraulic servomechanisms
- Circuit design
- Aerodynamic stability and control
- Flight analysis
- Autopilot simulation

A number of the positions now open are on supervisory levels. Inquiries are invited for positions at Lockheed's Engineering Centers in Van Nuys and Sunnyvale, California.

*Lockheed* **MISSILE SYSTEMS DIVISION** *research and engineering staff*

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## NEW PRODUCTS

### THREE-OUNCE RELAY

A new three-pole double-throw relay is available for electrical power control systems in military aircraft and other precision applications. Normally set for 20-volt pull-in and 9-volt drop-out, it has an electrical residual adjustment that may be changed to give a number of drop-out values between 9 and 19 volts. This adjustment may also be used in constant current circuits. Special compensation holds the maximum variation to 1 volt in pull-in and drop-out voltages over the entire ambient temperature range of minus 60 deg C to plus 125 deg C. Electrically good for 100,000 operations at 5.0 amp and 120 vac, the unit has a mechanical life of 2 million operations.—Joseph Pollak Corp., Boston, Mass.

**Circle No. 44 on reply card**

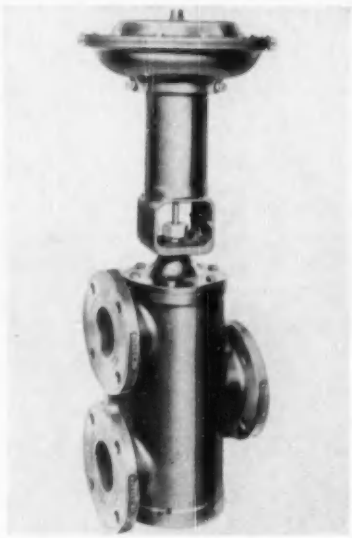
## FINAL CONTROL ELEMENTS

### QUIET SOLENOID

Current hum and other noise usually present in electrically-operated air valves are eliminated in this one by the rigid maintenance of very close tolerances on the spring, armature, and guide dimensions. Such a valve is recommended for noiseless control of air conditioning damper motors, as well as for control of pneumatic motors, valves, and other industrial equipment. When energized, the valve passes full air at supply pressures to 25 psi. When not energized, the valve will waste air from its outlet port and close the inlet. The 60-

cycle coil can be supplied for 115-, 208-, 230-, or 440-volt operation.—Powers Regulator Co., Skokie, Ill.

**Circle No. 45 on reply card**



### THREE-WAY BY-PASS

Featuring a constant total capacity regardless of inner valve position, these new three-way by-pass valves will direct flow to either of two outlets as required. Designed to be 100 percent tight closing, they are ideal for diverting applications, which would ordinarily require the use of two separate valves. Maintenance is simplified by a construction feature that makes it possible to change the discs and seat rings without removing the entire valve from the line. Maximum pressures range up to 250 psi at 406 deg F, and to 400 psi at 70 deg F. Sizes available now are 2½ in., 3 in., and 4 in. Valves are furnished for either proportional or two-position control.—Johnson Service Co., Milwaukee, Wis.

**Circle No. 46 on reply card**

### SERVO MOTOR

Reliability is the keynote of this servo motor, in which class H and class B materials assure safe operation between minus 60 to plus 120 deg C. Input is 115 vac, 400 cps. No-load speed is 5,000 rpm, and stall torque is 1.5 oz-in. Bearings are stainless steel with special high-temperature lubricants. One model has a 13-tooth, 120-pitch pinion; the other, a 15-tooth, 96-pitch pinion.—Basler Electronics, Inc., Highland, Ill.

**Circle No. 47 on reply card**

## NEW PRODUCTS

# COMPONENT PARTS

**as seen at ISA show . . .**

### DC TRANSFORMER

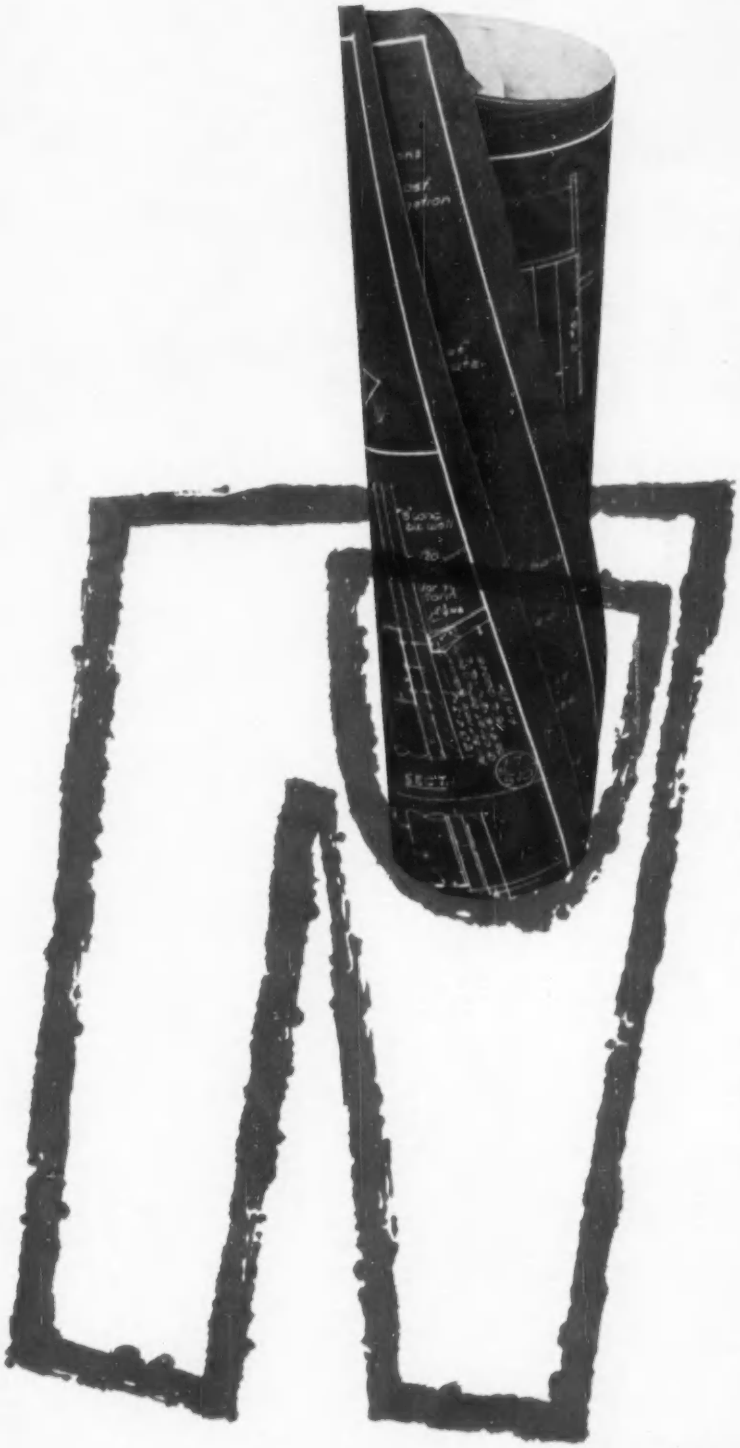
The tiny box being pointed out in the photo is a brand new transistorized dc transformer, now available for commercial, aircraft, and missile application. Switching transistors, coupled to a saturable core reactor, form a square wave oscillator circuit. The square wave is rectified by silicon diodes to form a dc output with extremely low ripple content. Output as high as 100 to 300 watts are possible, depending on ambient temperature. Operating efficiencies run to 90 percent.—The Ramo-Wooldridge Corp., Los Angeles, Calif.

**Circle No. 48 on reply card**

### DC SUPPLY

A new adjustable output, constant voltage dc power supply is now available. The compact, low-cost unit combines a constant-voltage transformer, a germanium rectifier, and a special high-capacitance filter section with small choke to yield laboratory standards of performance. Output voltage is regulated to within plus or minus 1 percent with supply voltage variations up to plus or minus 15 percent. Units are available in six stock models that provide output voltage ranges from 5 to 400 volts, and currents up to 7 amp.—Sola Electric Co., Chicago, Ill.

**Circle No. 49 on reply card**



# have an idea in your hip pocket?

Then we have an idea you'll be happiest at Firestone . . . where ideas are most likely to see the light of day and breathe the air of success. Here, too, you'll discover benefits and attitudes inspire more ideas, more success.

Ideas—and men with ideas—have kept Firestone at the top of the pioneers-in-progress list for 56 years. Right now, we're carrying forward the Army's vital program for the "Corporal," first surface-to-surface ballistic guided missile. This includes development engineering, field test and service, and missile and component production.

But the need for good men with good ideas grows . . . because Firestone plans to keep growing in this field. For instance, here are just a few specific needs—a few from a list too long to show in full:

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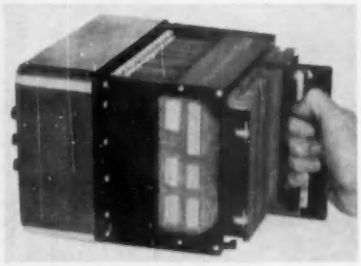
## NEW PRODUCTS



### 12-LB ARITHMETIC UNIT

Shown is a rear view of a new arithmetic control unit called the TRANSAC. Developed for inclusion in a large-scale computing system, the unit weighs less than 12 lb, occupies ¼ cu ft, yet contains nearly 1,000 transistors, 300 resistors, and 12 capacitors permanently dip-soldered into plug-in printed circuit cards. By using unique direct-coupled circuitry, the maker has eliminated many other components usually found in electronic computers. Ten "math" cards and seven "control" cards are plugged into the 10-in.-long unit to provide all arithmetic processing facilities. Philco Corp., Philadelphia, Pa.

Circle No. **50** on reply card

### UNLIMITED SHELF LIFE

A new solid electrolyte battery with practically unlimited shelf life has recently been developed for low current applications. The battery weighs only ¼ oz and is made primarily of silver, silver iodide, and vanadium pentoxide. It should give up to several decades' continuous service in applications such as maintaining a charge on capacitors in electronic circuits. In service, it can withstand temperatures ranging from minus 70 to plus 170 deg F with no appreciable change in voltage.—National Carbon Co., New York.

Circle No. **51** on reply card

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**NOVEMBER, 1956**

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(100) PHOSPHATING. Turco Products, Inc. Folder A-108B, 6 pp. Describes, and gives applications for, seven "Turcoat" materials, which are nonmetallic crystals, most of them phosphate compounds. Uses include aluminum protection, paint bonding, antifriction coating.

(101) PANEL INSTRUMENTS. Triplett Electrical Instrument Co. Form 81556-T, 4 pp. Contains full-size scales of various types of panels and dimensional diagrams of special instruments on which panels are used; describes typical external shunts and illuminated meters.

(102) GEAR-SPRAY VALVES. The Farval Corp. Bulletin 60-A, 8 pp. Covers well-designed little pneumatic system for spraying lubricant on the faces of gears. Pumping unit can be centralized or applied to a single panel of sprayers. Operating pressure is 80 psi.

(103) RECORDING ON FILM. Professional Goods Div., Eastman Kodak Co. Bulletin F1-2, 12 pp. A high-speed camera, normally not considered a control component, becomes one when it can detect a flaw in a piece of machinery. That's what Kodak claims for this unit.

(104) FURNACE, OVEN CONTROLS. Minneapolis-Honeywell Regulator Co. Condensed Bulletin B43-1, 44 pp. Describes controllers (strip and circular chart), circular scale pyrometers, thermometers, excess temperature cut-offs, etc.

(105) AIR CONTROL VALVES. Airmatic Valve, Inc. Spiral booklet, 60 pp. plus price list. A look at this Cleveland company's line. Sections carry data on these valves, among others: cam, flow control, interlock, pilot, pressure regulator, quick exhaust, sequence, solenoid, strainer, time delay, and booster.

(106) FLUID POWER. Published by National Fluid Power Association, distributed by Miller Fluid Power Div. of Flick-Reedy Corp. Booklet, 20 pp. Not many technical details here, but those given are presented nicely. Booklet amounts to a primer on hydraulics, and there's always room for another primer.

(107) CYPAK CONTROL. Westinghouse Electric Corp. Booklet TD 52-760. Photographs, drawings, text deal with Cypak magnetic controls and logic functions for industry. Included are basic "and", "or", "not", and "memory" functions, respective circuits, applications.

(108) SERVO ITEMS. Servo Corp. of America. Short Form Catalog SF 9901 (5½ by 8½), 16 pp. Industrial control systems, infrared measurement and control apparatus, communication and navigation devices broken down into building-block synthesis equipment, analyzers, amplifiers, assembly kits, etc.

(109) ADJUSTABLE-SPEED DRIVES. American Blower Corp. Bulletin 9819, 8 pp. Describes components and operation of Gyrol fluid drive, gives applications and advantages (acceleration and speed control, no-load starting), and presents variable- and constant-torque drive tables.

(110) PROCESS FLOWMETER. Industrial Development Laboratories, Inc. Catalog, 4 pp. Separation of the flow cell measuring elements from the fluid being measured, says the bulletin, assures sanitation and safety in processing chemicals, pharmaceuticals, food, etc.

(111) RADIATION PYROMETERS. Servo Corp. of America. Paper (8 pp.) presented at 1956 Winter General Meeting by W. Derganc and S. N. Howell, Servo Corp. Covers two new pyrometers having good spectral response, high sensitivity, rapid response, stability, and high accuracy.

(112) LEAK DETECTOR. Consolidated

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Electrodynamics Corp. Bulletin 1830, 4 pp. Deals with a helium-supplied unit that will detect one part of helium in 300,000 parts of air (or at least 1 x $10^{-9}$ atmospheric cc per sec). New design eliminates cold trap for condensable gases, provides variable pumping.

(113) PERMANENT MAGNETS. Magni-Power Co. Catalog 156, 16 pp. Illustrated with photos, dimension drawings, and charts of complete line of magnetic equipment—plates, sweepers, separators, drums and pulleys, grids, troughs, filters, and specialized equipment.

(114) FLOW CONTROL. Fluid Controls, Inc. Catalog 553, 8 pp. Hydraulic restrictor and needle valves and adjustable, pressure-compensated flow regulators are shown in schematic drawings. Capacities, pipe sizes, and dimensions are included.

(115) VALVES AND PUMPS. Hills-McCanna Co. Catalog G-56, 16 pp. Includes specs on diaphragm valves, tables of capacities on metering and proportioning pumps, and complete data (including a schematic) on a precision pump.

(116) PINPOINTS SHOCK. The Impact-O-Graph Corp. Bulletin, 4 pp. This machine, the Impact-O-Graph, rides with material being shipped and gives a time record of shock and rough treatment in handling and shipping. One- to three-dimensional recorders are clock- or motor-driven, with clock models operating without attention for 28 days.

(117) PHOTOELECTRIC SYSTEMS. Electronics Corp. of America. Bulletin PA 561, 24 pp. Contains detailed specs, complete descriptive data, and operational charts on Photoswitch packaged photoelectric systems for industrial control. New line of miniature and subminiature receivers and light sources also covered.

(118) MASS SPECTROMETERS. Consolidated Electrodynamics Corp. Bulletin 1824 B, 16 pp. Deals with applications, principles, ranges (mass 2 to mass 40, and mass 2 to mass 150, respectively) of models 21-610 and 21-620, both of which perform continuous or individual sample analysis.

(119) METERS AND CONTROLS. Bailey Meter Co. Bulletin G15-1, 8 pp. Charts measuring means, specifications, operating principles, ranges, etc., of more than 30 mechanical meters; similar data for electrical meters; and control components and accessories.

(120) MAGNETIC TECHNIQUES. Berkeley Div. of Beckman Instruments, Inc. Data File 109. Gives advantages of Ferristor miniature saturable reactor device over conventional vacuum tubes. This is the paper Berkeley's David A. Weinstein gave before the IRE convention in March.

(121) POWER PLANT EQUIPMENT. Copes-Vulcan Div. of Blaw-Knox Co. Bulletin 1022-A, 12 pp. Reviews, and illustrates with diagrams and actual instruments, combustion and boiler feed water control, pressure reducing, desuperheating, and automatic soot blowing.

(122) LOCK WASHER. Pioneer Stamped Products Co. Bulletin, 4 pp. Describes the stamped spring steel "Surelock" lockwasher that features a tight vibration dampening grip on the screw itself which dampens excessive vibration and increases the washer's locking ability.

(123) NEOPRENE NOTEBOOK. E. I. du Pont de Nemours & Co., Inc. No. 70 of a series, 9 pp. Lead article tells how the rubber industry tests and evaluates the properties of elastomers.

(124) "FACTS ABOUT HYPALON." E. I. du Pont de Nemours & Co., Inc. No. 4 of a series, 2 pp. This fairly new publication deals with a rubber for oxidizing chemical service.

(125) HEATING SAFETY DEVICES. McDonnell & Miller, Inc. Bulletin C-63, 8 pp. Treats 11 classes of safety devices for steam and hot water. Among them: boiler water feeders, low water fuel cut-offs, pump controllers, make-up water feeders for receivers, pressure and temperature relief valves, float-operated units.

(126) HEATING SERVICE GUIDE. McDonnell & Miller, Inc. Bulletin M-71 (3½x8½), 16 pp. A handy little booklet covering facts about right and wrong piping hook-ups, testing, trouble-shooting, and replacements, and stressing correct installation of feeder or cut-off and need for regular blow-downs.

(127) CARBON RESISTORS. International Resistance Co. Three bulletins (Forms S077b, S-084B, and S076A) give characteristics and applications for molded boron-carbon, deposited carbon, and molded deposited carbon resistors.

(128) DC POWER SUPPLIES. Sola Electric Co. Bulletin DC-235, 8 pp. Gives data for six standard-design, regulated units, featuring fixed-output and constant voltage, for intermittent, variable, and pulse loads, or for high-amperage loads. Applications, specifications, theory of operation covered.

(129) THERMOCOUPLE INSULATORS. Claud S. Gordon Co. Bulletin 300-56, 4 pp. Lists dimensions, sizes, and types of Gordon insulators for high thermal shock, high temperature, and high mechanical strength. Marginal notes cover principal properties of different materials.

(130) HYDRAULIC CIRCUIT TESTER. Schroeder Brothers Corp. Bulletin, 1 sheet. Treats a portable unit that can do its job without disturbing components. Temperature, pressure, and flow simultaneously measured. Pressure range 300-2,000 psi, maximum flow 50 gpm, weight 19 lb, price $490.

(131) PRESSURE MEASUREMENT. Kollsman Instrument Corp. Describes typical instruments for testing psia, psig, psid, vacuum or negative pressure, and

barometric pressure. All these "Kollsman Scientific" items are made by Kollsman and sold by Scientific Instrument Co.

(132) PLUG-IN COMPONENTS. Alden Products Co. Bulletin (6x8¼), 4 pp. Sections deal with a terminal card mounting system, basic chassis and plug-in packages, back connectors for bringing all leads to one point of check, quick-locking, piloting, fastening devices, monitoring units.

(133) VISCOSITY MEASUREMENT. Brookfield Engineering Laboratories, Inc. Bulletin, 8 pp. Describes the Synchro-Lectric Viscometer, which is made unique by its multi-speed rotational operation. Accurate to 1 percent of any range, makes a complete flow curve in less than 40 sec.

(134) X-RAY DIFFRACTION. General Electric Co. Publication 7A-3690, 4 pp. Discusses basic theory (Bragg's reflection method of analysis), definitions, analytical advantages, and applications in metallurgy, chemistry, etc. Includes typical patterns of fundamental methods of crystal study.

(135) WATER VAPOR MEASUREMENT. Scientific Instrument Div. of Beckman Instruments, Inc. Bulletin 498, one sheet. Covers the Beckman Electrolytic Hygrometer, which measures water vapor down to one part per million. Accuracy is to 5 per cent, takes samples as small as 100 cc per minute.

(136) ELECTROHYDRAULIC CONTROL. The Swiss Colony. Form S T-1, 4 pp. Tells how a simplified "little black box" (specially-wound coils, two electron tubes, a hydraulically-operated four-way valve) provides control of pressure, level, temperature, flow, and condensation.

(137) MAGNETIC MEMORY PLANES. General Ceramics Corp. Bulletin MP-105, 4 pp. Planes comes in eight standard frames, says the bulletin; each uses Ferramic S-1 magnetic cores (1 microsec switching time) or Ferramic S-3 core (5 microsec). One type is designed for random-access memories, the other for special register selection memories.

(138) FRACTIONAL HP MOTORS. Rae Motor Corp. Catalog, 16 pp. Shows ac-dc universal, dc shunt, and dc permanent magnet types. Units can be wound from approx 1/300 to ¼ hp and can accommodate governors. Also covers speed-reduction units for single or double reduction.

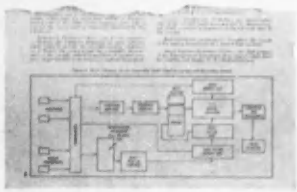
(139) REPEAT-CYCLE TIMERS. Eagle Signal Corp. Bulletin 323, 4 pp. Describes the Multipulse line of timers, which offers more than 300 standard time cycles (24 variable time ranges, each on a 1:3 ratio; 13 total time cycles available within each ratio). Charts tell how to select time range and time cycle.

(140) INSTRUMENT COUNTERS. Durant Mfg. Co. Catalog 400, 6 pp. Covers Durant's "Y" series (96 standard variations), which have the following characteristics: figure size $\frac{7}{64}$x$\frac{25}{64}$ in., speed 2,500 rpm intermittent, static torque 1 in.-oz, temperature range minus 60 to plus 85 deg C.

(141) SMOKE DENSITY MEASUREMENT. Industrial Div. of Minneapolis-Honeywell Regulator Co. Data Sheet 10.14-2a, one sheet. Shows how the Brooke smoke density measuring system combines with the Brown circular chart ElectroniK to indicate and record clarity of gas vented through a stack.

# APPLICATION LITERATURE

(142) DIGITAL SYSTEMS. BJ Electronics, Borg-Warner Corp. Folder includes 10-pg. booklet and 4-pg. bulletin. First seven pages of booklet are devoted to a discussion of the "building-block" components of digital systems. Component characteristics are given, and graphs illustrate the linearity of each component.



Following this discussion, four systems are described in detail with accompanying block diagrams. The above diagram, taken from page 8, represents a sequential multipoint measuring and recording system. The digital gage, a miniature electronic transducer, is fully covered in the bulletin. Curves showing the linearity of the gage, temperature effect, hysteresis, and transient response rise time are also included.

(143) MICRO-POSITIONING. Farrand Controls, Inc. Bulletin 819-1, 12 pp. Describes the application of linear and rotary positioning systems to the automatic control of machine tools Shows how these systems, called Inductosyns, have been

adapted to existing tools as well as to tools under development. Linear systems will position a machine carriage with a maximum error of 0.0001 in., and rotary systems are accurate to within 5 sec of arc. The accompanying photo shows some of the rotary systems as presented on page 11 of the bulletin.

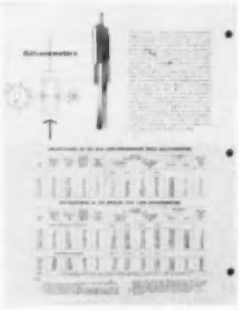
(144) SIZING MINIATURE T/C's. Thermo Electric Co., Inc. Bulletin 2,

10 pp. Contains comprehensive data on miniature bayonet thermocouples. Provides the user with a means of easily determining adapter and immersion lengths for a given hole depth, a method of selecting one thermocouple for various hole depths by using different adapter sizes, and a method for determining proper pipe-clamp adapter length. Terminals, connectors, and leads are covered in the last four pages.

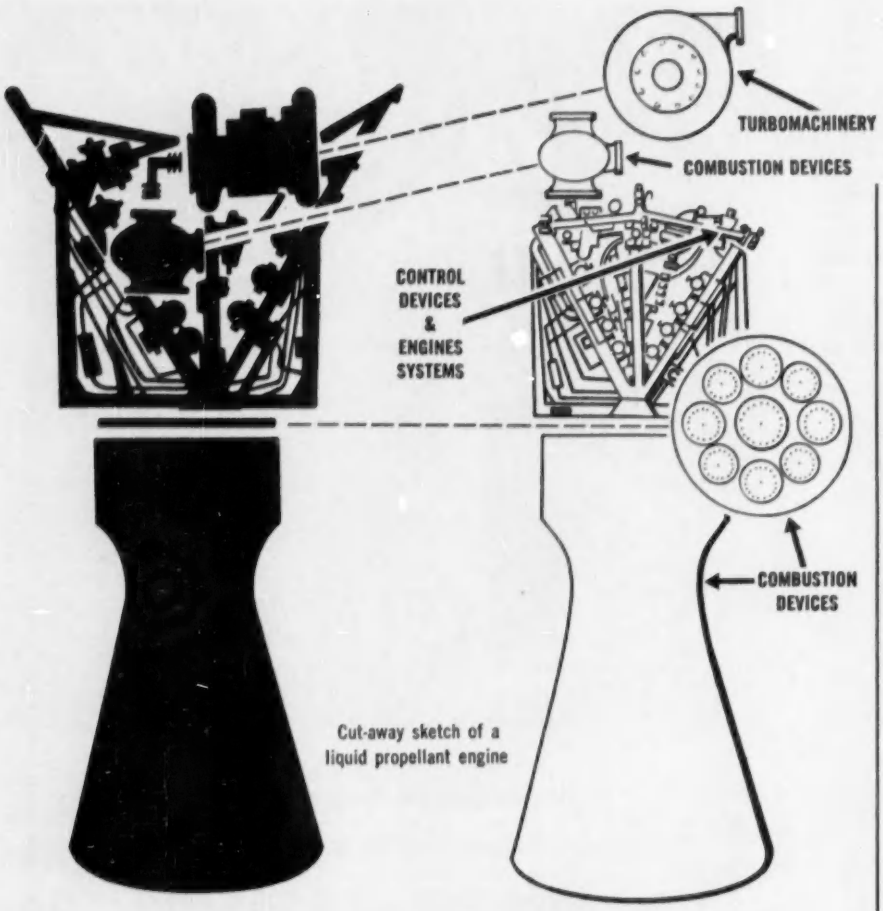
(145) STANDARDS SAVE MONEY. American Standards Association, Inc. Booklet, "Dollar Savings Through Standards", 40 pp. Shows how standardization in industry has resulted in definite economic benefits. Spells out these benefits in terms of dollars and specific percentages


of net savings. Over 75 documented case studies, covering 27 diverse industries, thoroughly acquaint the reader with results achieved to date. Well indexed, the booklet also contains a table of contents showing the industries reporting, and a list of abbreviations used in the text.

(146) PRODUCTS & PROGRESS. Consolidated Electrodynamics Corp. Bulletin 1305, 32 pp. In the form of a general catalog, reviews the manufacturer's line of instruments for analysis, control, and data processing. An outline of dynamic testing methods and a discussion of analog data-



recording systems precede a display of equipment available for these purposes. Complete specifications are given for os graphs, galvanometers, amplifiers, vibration and pressure measuring equipment, and digital data-processing systems including the SADIC and MilliSADIC families. Applications of analytical equipment for both laboratory use and process control are suggested. The bulletin also contains a brief explanation of the mass spectrometer principle.




Cut-away sketch of a liquid propellant engine

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## CONTROL PULSES

### *AUTOMATIC RANGE*

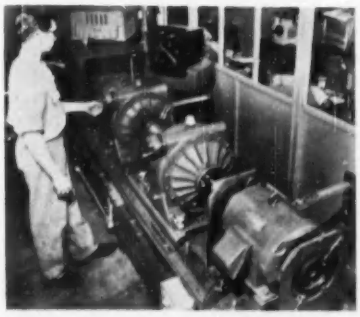
Minneapolis-Honeywell, which was never a company to let the grass grow under its feet, is doing just that these days, and making a lot of farmers happy in the bargain. The company's delicate temperature controlling instruments have been built into a little black box created by a Belgian inventor and manufactured in this country by Niamco, Inc., of Dallas. Six days after seeds and chemically-treated water have been placed in the box's seven incubator-type drawers, there is enough grass to feed ten cows. No soil is needed, since the mixture is automatically irrigated daily with dissolved nutrients.

### *DEMONSTATION KIT*

Hammarlund Mfg. Co. is selling automation in a satchel. Two small units, one representing a process and the other a control panel, are hooked together by a coil of ordinary telephone wire and plugged into the busy executive's wall socket. Hammarlund demonstrators stress the point that their equipment works just as well when the distance between the two units is miles as when it is inches. And in both cases, telephone lines do the job. The actual system is called COC (Centralized Operation Control).

### *TESTING TIME TOPPLES*

A reversible method of measuring input and output torque of variable-speed drive units saves time in testing for efficiency and other characteristics. The method is based on electrical measurement of bending strain in horizontal cantilever beams, the beams



which prevent the cradled drive motor and output dynamometer from rotating. The bending strain is measured by resistance wire strain gages and transmitted to a dial indicator on which torque up to 1,250 in.-lb. can be read. This new method greatly reduces the time required for each test, and makes reversing easy.

## WHAT'S NEW

### All Around the Business Loop

(from page 52)

for basic research problems only, and run on a part-time basis; most privately-owned computers are busy solving specific industrial and defense design problems; and the general-purpose university computing laboratory doesn't have many sources of support for necessary basic research.

### Companies A-Building

► A significant move by the Washington, D. C., laboratories of the **National Bureau of Standards** to 550 acres of land near Gaithersburg, Md. The shift from the facilities on Connecticut Ave. in Washington, which the bureau first occupied in 1903, is expected to take five years. Many of these buildings are temporary and most of them are outmoded, but all, because of the growth in stature of the bureau itself, are historically important.

Since 1903 the bureau's responsibilities have greatly increased, largely as a result of the rapid expansion of technology and scientific research. There is need now, therefore, for extensive programs of research and development in the physical sciences and engineering to meet the demands for new and improved standards and measurement methods, methods which the limited facilities in the District cannot foster. In their new rural setting, the bureau's scientific programs will be free of such urban interferences as mechanical, electrical, and atomospheric disturbances, and conversely, will not interfere with community life. The decision to leave the Connecticut Ave. site followed conclusions that renovation would amount to more than half the estimated cost of a complete new facility and that space for further expansion was lacking.

► Expansion by **Perkin Engineering Corp.** through purchase of a new building adjacent to present facilities in El Segundo, Calif. The company intends to use the additional room for manufacture of such standard items as dc power supplies, ac line voltage regulators, and airborne radar power supplies, and for initial work in sheet metal fabrication and production of transformers and magnetic amplifiers.

► New facilities for research and devel-

## WHAT'S NEW

opment for **Lear, Inc.**, at Santa Monica (Calif.) Municipal Airport. The building, next to Lear's other Santa Monica plants, houses the West Coast engineering branch of its **Grand Rapids (Mich.) Div.**, a group of about 100 engineering specialists whose products include a stability system for the F-104A interceptor, and a missile autopilot. The additional room will allow wider work in machine-tool control, damper system design for aircraft, and drone and missile control.

▶ A home (250,000 sq ft) for **Minneapolis-Honeywell's Transistor Div.** in Boston. Activities in the building, formerly known as the Hathaway plant, will be integrated with Honeywell's **Doelcam Div.**, also in Boston. In fact, many of Doelcam's products will be manufactured in the new building. Employment there is expected to reach 1,500. Also for Honeywell: a new aeronautical plant ($4 million) to be built near St. Petersburg, Fla., for its **Aeronautical Div.** Receipt of additional government contracts prompted construction of the 207,500-sq-ft plant, which will employ 1,500 by mid-1957. It will be Honeywell's first facility in Florida.

▶ A half-million-dollar plant in Westchester, Calif., for **Daystrom Pacific Corp.**, a subsidiary of **Daystrom, Inc.** DPC and its **American Gyro Div.** will move into the 50,000-sq-ft office-research-manufacturing facility next February. Among its features: dust-free atmosphere, controlled temperature, a lunch patio, and a 250-car parking lot.

▶ A one-story office and manufacturing structure (5,500 sq ft) in Westbury, N. Y., for **Consolidated Avionics Corp.**, a subsidiary of **Consolidated Diesel Electric Corp.**

▶ Additional space (55,000 sq ft) in Stanford Industrial Park for **Levinthal Electronic Products, Inc.** The new plant, now a-building, will augment present installations in Redwood City, Calif. Administrative, research, and engineering activity will concentrate on high-power microwave equipment, scintillation-crystal development, and medical electronic apparatus.

▶ A new home (102,000 sq ft), just completed in Waltham Research & Development Park, Waltham, Mass., for **Baldwin-Lima-Hamilton Corp.'s** year-old **Electronic & Instrumentation Div.** The $3-million facility brings together under one roof three companies acquired by B-L-H in the past few years as well as the **Testing Equipment Dept.** of its **Eddystone Div.** Key personnel from the four units have

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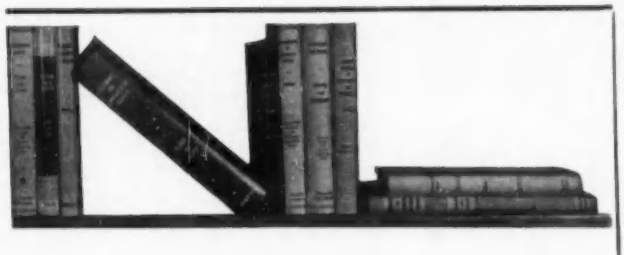

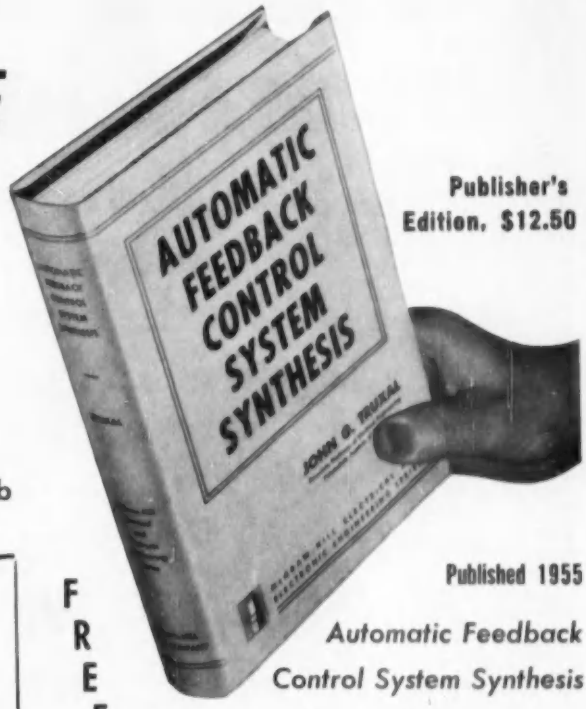


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## WHAT'S NEW

transferred to Waltham to take new posts in the budding division. Among them are Arthur Ruge, appointed part-time special consultant; Frank F. Hines, staff consultant; Edgar J. Jones, chief engineer for the SR-4 strain gage section of the division; Joseph Kriz, director of manufacturing; and John Pietruszka, superintendent of manufacturing. Ruge, Hines, and Jones were president, executive vice-president, and vice-president for engineering, respectively, of **Ruge de Forest, Inc.**, at Cambridge, Mass.; Kriz was manager of the **Electronics Div.** of **O. S. Peters Co.** at Washington, D.C.; and Pietruszka was manager of **Sonntag Scientific Corp.** at Greenwich, Conn. Twelve other Peters men and seven others from Sonntag have also taken up new quarters in Waltham. Consolidation of the widely scattered B-L-H properties not only puts a brighter light on the big locomotive maker's line of testing instruments, strain gages and testing systems, and testing machines, but promises a one-third increase in their production. Estimate: $900,000 worth of output per month by the end of this year.

▶ A third plant for **National Electronics Corp.** in Los Angeles, to house the company's general offices.

▶ A new building in Burbank, Calif., for many of the departments of **Weber Aircraft Corp.'s** young (14-month-old) **Electronics Div.**, which makes, among other things, a low-cost, high-performance analog computer. Amplifiers, oscillographs, and complete systems will be turned out here.

▶ More room for **Erie Resistor Corp.'s Electro-Mechanical Div.** in Los Angeles. Under Joseph Martin, who comes to Burbank from Erie as supervisor, the plant will supply the West Coast area with Erie assemblies, including computers, communications devices, and missiles and other military equipment.

▶ A home (which will eventually expand to 75,000 sq ft) in San Ramon, Calif., for **Aerojet-General Corp.'s** new **Aerojet-General Nucleonics** subsidiary. Special production layouts have been designed for phases of the subsidiary's portable, self-contained AGN 201 reactor, which Aerojet calls the first mass-produced model. It sells for $100,000.

▶ Among recent acquisitions: The **Machine Products, Tool & Die,** and **Electronic Components Mfg. Divs.** of **Burroughs Corp.'s Haydu Brothers** subsidiary, by George and Zolton Haydu, who have formed **Haydu Elec-**

## WHAT'S NEW

tronic Products, Inc., out of these facilities. Planned for production are components for electronic tubes, precision burners for tubes and glass works. George Haydu is president of the new Plainfield, N. J., concern.

▶ Also: **Triad Transformer Corp.** and its Indiana subsidiary, **Ultrad Corp.** (electronic transformers, reactors, toroid coils, wave filters, etc.) by **Litton Industries; Western Design & Mfg. Corp.** (a special hydraulic pumping jack for oilfields; motors, actuators, cooling equipment, and blowers; and aircraft and missile components) by **U. S. Industries, Inc.; PSP Engineering & Mfg. Co.** (aircraft solenoids) by **Induction Motors Corp.**, and **General Logistics Corp.** (load control and tie-down equipment for aircraft and trucks) by **Aeroquip Corp.**

### Important Moves by Key People

(from page 46)

▶ **Raymond J. Barclay,** who has been with General Electric since 1942 in various capacities, has been named manager of manufacturing for the Industrial Computer Section. His duties will consist of overseeing production of the section's line of analog and digital computers.

▶ Two directors of Ramo-Wooldridge have moved up to vice-president of their respective departments. They are: **V. G. Nielsen,** formerly director of administration and finance, and **Gordon P. Saville,** formerly director of military requirements. Nielsen has also been assistant dean of the Harvard Graduate School of Business Administration and director of administration of Hughes Aircraft Co.; Saville, a retired Air Force major general, was most recently deputy chief of staff for development, Headquarters, USAF.

▶ Lear's LearCal Div. has established a new Advanced Development Dept. to guide expansion in system development, studies, and analyses, and has put **Dallas V. Franke** in charge of it. Franke, formerly research director and sales manager of Cal-Tronics, has also been with American Electronics (chief engineer), Hughes Aircraft (research engineer), and Gilfillan Bros. (senior engineer).

▶ **Norbert Weber,** a native of France who has been in this country since 1948 as senior project engineer and manager of industrial sales in Philadelphia and Buffalo for Beckman Instruments, has been named European

## WHAT'S NEW

manager of Fischer & Porter's International Div. He will work out of The Hague, Netherlands, coordinating engineering, production, and sales of the company's four European manufacturing affiliates and nine engineering representatives.

▶ Among the "big names" being brought in on Ford Instrument Co.'s closed-cycle reactor projects (CtE, October, p. 42) is **Pio Franco Martinuzzi,** who will be technical consultant to the vice-president for engineering while continuing as professor of mechanical engineering at Stevens Institute. Martinuzzi's specific area at Ford will be the Atomic Energy Section, where he is expected to make full use of his knowledge about gas turbines. He is considered an international authority in this field. In 1945 he returned to his native Italy to head the Gas Turbine Section of the Italian National Research Council. Later he gave a series of lectures in this country for the ASME and in 1948 was named Calvin Rice Lecturer by the association. He taught at Cornell before joining the Stevens faculty in 1952.

▶ **Joseph L. Borden,** who has been with Perkin-Elmer Corp. since 1949, most recently in application engineering and sales work in connection with process control instruments, has been named head of the Infrared Instrument Development Section of the Engineering & Optical Div. Before coming to Perkin-Elmer, Borden was with Servo Corp. of America and The Glenn L. Martin Co.

▶ Armour Research foundation has promoted **Harold L. Garbarino** to assistant manager of the Electrical Engineering Research Dept. A specialist in electromagnetic apparatus and electronic components, Garbarino takes charge of the ARF Electric Machines, Components, and Measurements Section, where he had been supervisor since 1954. He came to the foundation in 1951 from General Electric, where he had been a development engineer.

▶ Richardson Scale Co. has appointed two veteran company men to vice-presidents. They are: **Arthur J. Burke,** with Richardson for 20 years and chief engineer since 1951, and **William Hamilton,** a 25-year man whose last position was midwest manager.

▶ BJ Electronics, a unit in the Byron Jackson Div. of Borg-Warner Corp., has appointed **John R. Harkness** vice-president and general manager, and **Paul J. Holmes** technical director. Harkness comes to BJ Electronics from Kearfott Co., where he had been

Western Div. general manager. Holmes, whose headquarters are at the company's new facility at Santa Ana, Calif., also takes on the duties of technical consultant in electronics to the Borg-Warner Research Center at Des Plaines, Ill.

▶**Erwin Tomash,** formerly vice-president of Telemeter Magnetics, Inc., is now president. His election follows the resignation of **William K. Squires.**

▶Planning Research Corp. has added **Joseph J. Putegnat,** formerly chief of operations of the analysis office at White Sands Proving Grounds, N. M., to its staff as an associate. He will make supply and maintenance studies in connection with missile systems.

▶Two former National Bureau of Standards men are back on the bureau's payroll. They are: **Almon W. Spinks,** who came to NBS in 1929, left in 1953 to join the Diamond Ordnance Fuze Laboratory, and now is back as head of the Aircraft Electrical Network Laboratory; and **Harvey W. Lance,** whose affiliation with the bureau began in 1948 when he was named physicist and electronic scientist in charge of microwave research in connection with missile guidance systems. In 1953, when Lance left the bureau, he was head of the Microwave Systems Div. He returns as chief of the Calibration Center now under construction at NBS Boulder (Colo.) Laboratories. Neither man really "resigned" from NBS: they simply accompanied their respective organizations when these organizations spun off on their own. The bureau's new assistant chief of the Calibration Center is **Wilbur F. Snyder,** a 30-year man who most recently was assistant to the chief of the Radio Standards Div. and acting chief of the Calibration Section.

▶**Mark M. Lotkin,** formerly in charge of the Mathematics Section at RCA Service Co., Patrick AFB, Florida, has taken on similar duties with the Research & Advanced Development Div. of Avco Mfg. Corp. He is known as a specialist in applied mathematics and computing machines.

▶A recent addition to Panellit's development staff is **Donald F. Gimpel,** who takes charge of electronic projects. Gimpel, who has been with Armour Research Foundation, Sears Roebuck & Co. (he helped develop the latter's order entry station machine), and Northwestern University (where he received his PhD and worked on analog computers), will also assist in Panellit's systems research program.

▶**Eli M. Goldfarb,** a new senior project engineer at Levinthal Electronic Products, Inc., has been as-

*(Other important moves, page 209)*

# ABSTRACTS

## Simulating Chemical Reactor

*From "Analog Computer Simulation of a Chemical Reactor" by T. L. Batke, R. G. Franks, and E. W. James, E. I. du Pont de Nemours & Co., Inc. ISA paper 56-7-2, presented at the ISA Conference, New York City, Sept. 17-21, 1956.*

The chemical reactor under investigation by the authors exhibited instability due to exothermic type reactions, distributed parameters, and reactor recycle. Trial and error approaches to improving process operation could, of course, have been made directly on the plant, but this was not practical because of the loss of production and other economic factors involved. Therefore the process was simulated, to a great degree of accuracy, on a general-purpose analog computer at Electronic Associates' Princeton Computation Center. Once the basic building blocks were determined for the simulation, the various adjustments of time constants, dead time, and scale factors were made. Comparison with actual plant records showed an excellent simulation had been provided. Trial and error changes then were made on the computer to find out what corresponding changes would have to be made on the plant to reduce instability and maintain required product quality and quantity.

Figure 1 shows the recycle reactor process described by the authors and

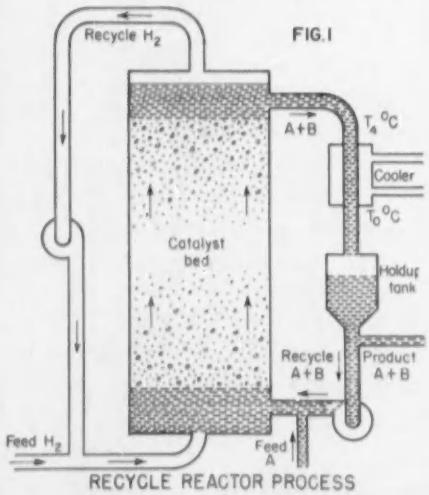

FIG.1 RECYCLE REACTOR PROCESS

simulated on the analog computer. Since the computer simulates the dynamics of this reactor, it was first necessary to determine the dynamics.

In discussing their analysis of the reactor before it was mechanized on the computer, the authors present an excellent review of the dynamics and considerations involved in such chemical processes. "This reactor is a typical example of a system which yields a set of partial differential equations with time and distance (path length through reactor) as independent variables. This class of equations must be approximated by replacing spatial derivatives with their finite difference equivalents. This merely means that the reactor is split into an arbitrary number of zones (in this case four). It is assumed that each zone has a uniform temperature and composition. The reagents flow successively through these zones carrying the temperature and composition of the preceding zone to the next zone. The system equations are derived by a heat and material balance . . ."

Figure 2 shows how the system is divided into four zones to simulate the recycle reactor process. Development of the heat and material balance equations are given by the authors.

▶ material balance—

$$C\frac{dA_n}{dt} = A_{n-1} - Q\,A_n - C\,f(T_n)\,A_n$$

▶ heat balance—

$$C_H\frac{dT_n}{dt} = Q\,T_{n-1}\,c - Q\,T_n\,c + h\,C\,f(T_n)\,A_n$$

Simple integration and division by the constant on the left side isolates the required parameters: A, the composition, and $T_n$, zone temperature, thus:

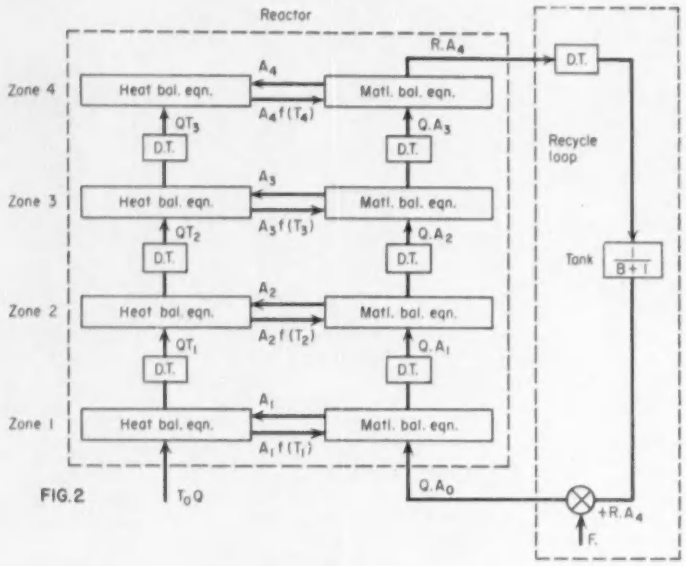

FIG.2

$$A = \int\left(\frac{Q}{C}A_{n-1} - \frac{Q}{C}A_n - f(T_n)\,A_n\right)dt$$

$$T_n = \int\left(\frac{Q\,c}{C_H}T_{n-1} - \frac{Q\,c}{C_H}T_n + \frac{h\,C}{C_H}\left[f(T_n)\,A_n\right]\right)dt$$

These equations, one for each of the four zones, can be mechanized with standard computer equipment and techniques.

The transport lags between zones, as shown in Figure 2, are simulated with a simple dead time, while the dead time in the recycle pipe requires an eight-root approximation. The details for mechanizing these dead times are given in the paper. Figure 3 shows mechanization of the material balance equation.

On the simulator the scale factors, connections, and dead time are adjusted so that the four-zone approximation adequately represents the actual distributed-parameter system. "Having obtained a satisfactory computer simulation of the plant reactor, it was now possible to test out various schemes for overcoming the instability. The first experiment was to increase the re-

cycle tank size by decreasing the appropriate attenuator setting and noting its effect on voltage oscillation. It was found that a tank 32 times greater

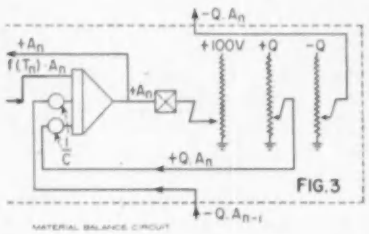

FIG. 3

MATERIAL BALANCE CIRCUIT

was necessary to damp out the oscillations, and a high pressure tank of this size was not a feasible proposition . . . Several other ideas were examined which required changing the reactor size, the height of the catalyst bed, decreasing catalyst particle size, increasing recycle flow, controlling *F* flow from other measured variables, and so on. The sum total of the results from the tests provided a sound basis for making changes to the reactor system, which have since proved satisfactory."

This paper makes a worthy contribution toward a better understanding of chemical process plant dynamics and how they are simulated on an analog computer to investigate improvements. Two pages relating to the paper—references and a table on computer building blocks—are missing from the Proceedings, but this omission does not detract from the good information presented.

## X-ray Measures Coating

*From "X-ray Tin Thickness Gauge" by D. D. Doran, Bethlehem Steel Corp. ISA paper 56-22-2, presented at the ISA Conference, New York City, Sept. 17-21, 1956.*

Electrolytic tinning of sheet steel on a continuous basis introduced many complications which did not previously exist when tin was applied by hot dipping. Hot dipping applied about 1.5 to 7 lb of tin per 100 lb of steel. Coating thickness accuracy was not too important because of the high percentage of tin used and because control of coating weights in the hot dipping method was too difficult.

But with electrolytic tinning coating weights dropped to about 1 percent, thickness control became possible, customers demanded differential coatings, and production speeds increased tenfold. With this faster production, however, thickness errors means either the customer does not get what he paid for or he receives too much tin. To prevent undercoating, the operator usually plates a little too

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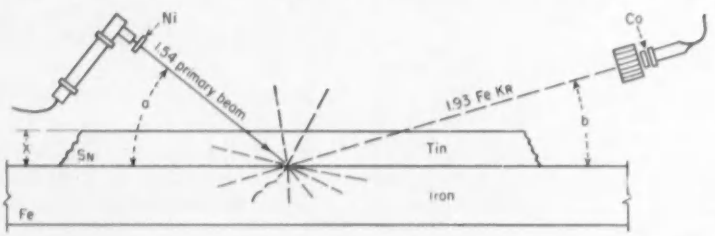
much, which means excess tin is given away. "The trick is to provide a minimum of excess tin and still never have to rerun a coil for being under weight."

Plating with just 0.02 lb less of tin per 100 lb of steel means quite a savings. With the current price of tin at $1.00/lb and a typical monthly production rate per line at 35 million lb of steel a savings of $21,000 in three months can be realized. This potential savings justified the development and use of a good, reliable, and instantaneous gage on the high-speed production line.

Conventional x-ray thickness gages were not practical here, for they only measure the total thickness of the sheet steel and its tin coating; thus variations in tin thickness are obscured by larger variations in the sheet metal. For this reason the gage covered here uses the method of x-ray fluorescene described in the figure.




The primary x-ray beam, with a frequency of 1.54A, penetrates through the tin and hits the surface of the iron. This causes fluorescence in all directions and the iron now acts as a source of x-rays, but at a different frequency, namely 1.93A.

The total absorption of the x-rays occurs through the tin at 1.54A primary beam and 1.93A fluorescent beam and is determined by the following relationship:

$$\frac{(I)}{(I_o)_{total}} = e^{-(\mu_p \rho/\sin a + \mu_s \rho/\sin b) x}$$

where:

$I$ = x-ray intensity
$I_o$ = initial x-ray intensity for $X = 0$
$\mu$ = mass absorption coefficient of the material
$\mu_p = 247$ for tin at 1.54A
$\mu_s = 470$ for tin at 1.93A
$\rho$ = density of material, 7.31 for tin
$X$ = thickness of material, cm

Although the absorption coefficients are desirably high, the tin thicknesses are too low. To increase the effective absorption, angle $b$ is kept small, about 20 deg, while angle $a$ equals 70 deg. The angle between the detector and the x-ray tube is maintained at 90 deg for mechanical convenience.

Substituting the given values in the above equation yields an equation from which the thickness can be found:

$$\frac{(I)}{(I_o)_{total}} = e^{-11,900X}$$

The accuracy of the total instrumentation is about 0.01 lb of tin per 100 lb of steel; the output reading appears on a recorder with a logarithmic calibration derived from the exponential absorption relationship. Full scale is from 0 to 0.7 lb of tin per 100 lb of steel.

Mill operators see the results of the measurement on the recorder but do not adjust the instrument. Responsibility for the gage resides with the metallurgical groups, which checks the unit once each shift. When necessary, calibrations are carried out automatically simply by closing a switch that operates a traversing mechanism and initiates a programming relay. Standardization takes 4 min.

Originally the gage was installed as a supplemental instrument in mills. "Operating personnel have recently indicated that they would like to use the gage exclusively so that some of the facilities and manpower now employed for coating analysis can be used to better advantage."

### Instrumenting a Reactor

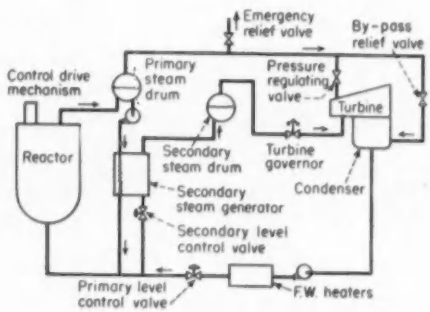
*From "Instrumentation For A Nuclear Powered Electrical Generating Station" by Burns E. Woodward, Atomic Power Equipment Dept., General Electric Co. ISA paper 56-7-3, presented at the ISA Conference, New York City, Sept. 17-21, 1956.*

The principal difference between instrumentation used in the control of nuclear electric power generating stations and that in conventional steam generating stations is the reactor itself, the counterpart of the boiler in present fossil-fuel generating stations. In many respects the instrumentation and control for turbine, generator,

and steam and water handling equipment will be similar for both types of installations.

The inherent self-regulation and automatic feedback of the dual-cycle boiling water reactor simplifies control, although complex instrumentation problems still arise because of the necessity for remote control and for protection of personnel and surrounding territory from effects of radiation. Although it is important that safety precautions and instruments shut down the reactor in case of danger, the output of power from the station must not be jeopardized by inadvertent and unnecessary "scramming". Otherwise, the many customers relying on a constant source of electricity will be seriously inconvenienced. Thus, the plant and its instruments must be designed to shut down only when there is a real danger to life and property. "New devices which are added to the basic plant are those for control of the nuclear process, and measurement of radiation for personnel and environmental protection."

The figure shows the basic flow and control diagram for the dual-cycle




boiling water reactor. "The heat generated in the nuclear reaction produces steam which rises in the reactor vessel. The steam bubbles, or voids, affect the density of the water in the core, and thereby influence the moderating action in the core. More steam bubbles in the core result in less moderator being available and the effect is less nuclear reactivity. If the percentage of steam (voids) is reduced, the opposite effect results. . . .

"At steady state, approximately half of the steam used in the turbine will originate in the primary cycle. The rest will be taken from the secondary steam generator and when an increase in the station load is called for, additional steam will be obtained by action of the turbine governor opening further the secondary admission valves. This will result in increased flow of steam in the secondary loop and will decrease the temperature of the water

## ABSTRACTS

being recirculated to the reactor. Since the recirculating water is cooler, it will remain liquid for a longer interval during its passage through the reactor. The consequent increase in density will result in an increased nuclear reaction since additional moderator will be available. From this standpoint the system is self-regulating and stable."

Because of this self-regulating feature the reactor power can vary from 100 percent to 40 percent, to meet electric generation load changes, without any adjustment of the control rods. Since control rods need not be manipulated for normal load changes, they can be maintained in given positions. Only when an emergency shutdown (scram) occurs will the rods move, and then they will be driven to their power-limiting position.

Other devices are available to initiate the scram circuit in case the following conditions exceed their present control points: high reactor pressure, low condenser vacuum, loss of circulating water, loss of feedwater, and loss of auxiliary power. Neutron monitoring of the reactor core also initiates scramming when any two parallel channels, of the several monitoring the core, indicate excessive concentration.

Other aspects of equipment and their instrumentation discussed include steam drum level control, turbine controls, air ejectors, demineralization, feed pump, feedwater heaters, and process radiation monitoring.

### Analysis With Color

*From "Differential Photoelectric Colorimeter for Continuous Process Control" by F. R. Rolfson, Shell Development Co., and N. S. Waner, Hallikainen Instruments. ISA paper 56-1-4, presented at the ISA Conference, New York City, Sept. 17-21, 1956.*

Among the instruments used for continuous process control is the differential photoelectric colorimeter. The authors have designed a unit embodying increased sensitivity and stability and lower cost for use in a wider variety of applications and in a greater number of streams. Color measurement enables rapid detection of upsets in distillation columns and minimizes the possibility of operator errors in spite of a complex arrangement of valves and pipes.

In colorimetry, the transmittance of radiant energy is measured in a visible region through a sample. To be effective and sensitive there should be a

sharp variation in transmittance over the visible spectrum. This variation occurs in nearly all petroleum products, and is particularly sensitive in the green region, about 510 millimicrons, as shown in Figure 1.

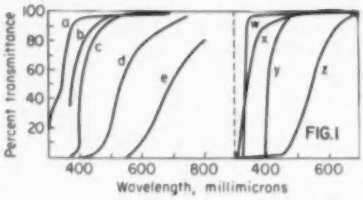


FIG. 1

In a simple single phototube colorimeter the sample is introduced between a light source and a phototube, and the tube's output current indicates the transmittance (hence color) of the sample. Any variation from normal transmittance *I* would be plus or minus *i*. Thus, the total output would be *I* plus or minus *i*, and the system would not be too sensitive to small changes. However, if two phototubes are used, their outputs can be connected differentially, and the output would simply be plus or minus *i*. The sensitivity and detectability of small changes in transmittance would thus be improved.

In the colorimeter described by the authors the light beam splits, one beam going through the sample onto one phototube and the other beam through an adjustable aperture onto the other phototube. The aperture provides optical balance and compensates for changes in source intensity. A deviation in transmittance from the value set up by the reference aperture causes an unabalance current, indicating either a light or dark sample.

Figure 2 shows the partial wiring diagram of the alarm colorimeter.

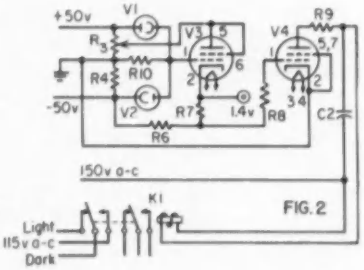


FIG. 2

Here, the phototubes feed a cathode follower, which in turn fires a thyratron when the unbalance signal is positive. The coil of a double-pole double-throw relay in the thyratron's anode circuit pulls in on a positive unbalance, and red and green lights operated by the relay contacts indicate either light or dark samples. An-

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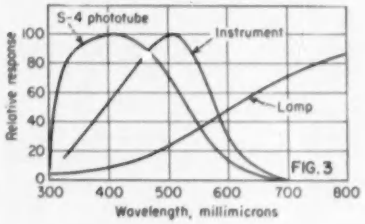
other set of contacts feeds any existing alarm system.

Normally a colorimeter requires a monochromatic light source for high sensitivity. The authors, however, use a standard incandescent source and obtain a peak response in the 510 millimicron region by fortuitous combination of the phototube spectral response and the characteristic of the lamp. Figure 3 shows the individual




response of the phototube, the lamp characteristic, and the peaked response of the combination.

This instrument has been designed for rugged plant use in hazardous areas. Design problems for such difficult applications share the discussion with physical design, the effect of temperature on the spectral response of the phototubes, and requirements for stability and sensitivity.

The paper concludes with several applications for the color alarm. "Although initially developed for use in refineries, the instrument has been successfully employed in chemical, pharmaceutical, paper processing, water treatment, and sewage plants. In the refineries these units are being used to monitor the color of kerosenes, lubrication oils, gasoline, and other hydro-carbons in column reflux streams, as well as product streams. Color is being checked in other processes on such material as cotton seed oil and 98 percent glycerine. In one plant the color alarm is being used to detect decomposition in a 70 percent hydrogen cyanide solution. Here the normally clear solution exhibits a light straw color on decomposition which then operates the alarm."

### Analysis With Refraction

*From "The Refractometer—A New Analytical Tool For Process Control" by P. W. Collyer, Barnes Engineering Co. ISA paper 56-1-2, presented at the ISA Conference, New York City, Sept. 17-21, 1956.*

Laboratory use of refractive index for liquid product analysis has been well-known for many years, but it is

only recently that chemical and petroleum companies have adapted this measuring technique to continuous on-stream monitoring and control, developing their own instrumentation to suit particular requirements. Three commercially-available industrial refractometers are now on the market, however, a sign that widespread application of this important measuring method in the near future is assured.

The refractometer operates basically on the principles established by Snell's Law, which states that the refractive index is related to the bending, or refracting, observed when light crosses a boundary between two unlike materials. Thus:

$n \sin i = n' \sin r$

where $n$ and $n'$ are the refractive indices of two materials and $i$ and $r$ are the angles between the normal (to the interface between the media) and the incident and refracted light beams. If the sample is contained in a glass reference cell with a refractive index $n'$, then the refracted angle will vary with changes in this refractive index. Thus a detecting means, such as a phototube, will have to move to observe these changes.

However, using a differential cell containing sample $n$ and a reference liquid $n'$, as shown in the figure, pro-


vides certain advantages. As long as the refractive indices are the same, whether it be 1.2 or 1.7, the light emerges in the same direction. But any small change in the sample's refractive index shifts the angle slightly, and this deviation is proportional to the difference in the indices, not to their absolute values. A mirror and a slightly oblique incident light beam separates the light beam entering the cell from the light beam leaving it. A servo-driven optical system continuously restores the light beams to photocells. The amount of deviation from the reference refractive index is indicated by a pointer arrangement attached to the servo drive. With proper compensation for temperature and care in design of the light source the refractometer can measure and indicate to the fourth or fifth decimal any deviation in refractive index.

The paper discusses the heat exchange needed between the reference and sample to minimize refractive index errors with difference in tempera-

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tures, as well as the practical requirements for a sample cell to assure long-time use in a plant with a minimum of maintenance.

Typical applications mentioned by the author are in the fields of:

- fractionating
- blending or analysis of two components in a mixture
- adjusting concentrations of aqueous and other liquids
- monitoring such processes as hydrogenation of edible oils
- monitoring the effluent from a chromatographic column

### Mass-Number Analysis

*From "Mass Spectrometer in Process Control" by Henry Landsberg, Consolidated Electrodynamics Corp. ISA paper 56-6-1, presented at ISA Conference, New York City, Sept. 17-21, 1956.*

Looking forward to the time when fully automatic process plants will be technically and economically feasible, the author sees a need when this time comes for stream analyzers in general and mass spectrometers in particular. "A very significant advantage of the mass spectrometer is that it is not tailored for a particular stream, but can be programmed to analyze on a repetitive cycle several streams of widely differing compositions. Because of these inherent advantages, the mass spectrometer shows great promise as a suitable primary element in the automatic process plant of the future. Until such plants are feasible, the instrument can be used effectively in the control of many individual processes as demonstrated by applications to be discussed."

However, before describing some interesting applications, Landsberg reviews the type of information obtained at the output of a mass spectrometer. "Each compound has a unique spectrum consisting of peaks at the mass of its molecule as well as at all masses of the various fragments of its molecule. . . . Concentration of a constituent in a mixture may be determined simply by the magnitude of a single peak provided that it is unique only to that constituent."

Control of the process using the sequential signals from the mass spectrometer, which indicate the constituent concentrations, will eventually require a small digital computer to compute corrective signals.

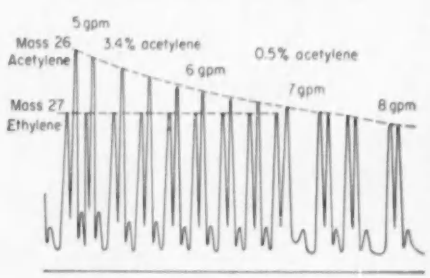
The author reviews a number of successful plant applications of the mass spectrometer as a primary ele-

ment for measuring and recording. These uses are in a sulfur recovery plant, selective absorption in an acetylene-ethylene plant, and in vacuum refining of metals.

The sulfur recovery plant produces elemental sulfur from hydrogen sulfide, which is a by-product of natural and refinery gases. The effeiency of the process depends on controlling the amount of air, so that the relationship $2H_2S$:1$SO_2$ can be maintained.

The process mass spectrometer monitors the process reactor effluent, which, since the reaction is never complete, contains $H_2S$ and $SO_2$. "The mass spectrometer equipped with an automatic peak selector was set to alternately monitor $H_2S$ and $SO_2$ at masses 34 and 64 respectively." Chart recordings then indicate the amount of reaction not completed and thus allow the ratio to be determined. Process variables can be adjusted on the basis of this information, and the reaction kept to minimum incompletion. The more complete the reaction, the more sulfur (hence dollars) yielded by the process. Thus, the average recoverable loss was about 1.3 tons per day, or about $15,000 per year.

The application of the mass spectrometer to a selective absorption process is another example of the versatility of this type of stream analyzer; in fact, in this case a signal could be obtained for automatic process control. Here, the spectrometer maintains "efficient operation of an absorber column by continuous analysis of the absorber off-gas in an acetylene-ethylene plant. . . . It is desired in this operation to maintain the flow of absorbent so that the maximum amount of acetylene and essentially no ethylene is absorbed. . . . It is known from the spectra of ethylene and acetylene that ethylene contributes equally to masses 26 and 27 whereas acetylene contributes only to mass 26. The difference between these peaks is, therefore, indicative of the acetylene concentration."




The figure shows the record of peak concentrations of these two constituents obtained for various absorbent

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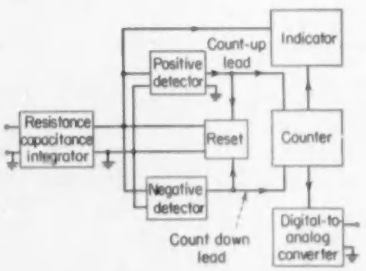
flow rates. At 5 or 6 gpm the acetylene loss in the off-gas is relatively large. Increasing the absorbent flow reduces this loss and brings the peaks closer together. When they are identical, loss of acetylene stops. Thus optimum absorption can be obtained by matching the absorbent flow to the acetylene content in the feed gas. "Direct control in this application would be relatively simple by incorporating a device which would obtain the difference of these peaks and supply a net signal for the control of the absorbent flow."

### Large-Storage Integrator

*From "Wide-Dynamic-Range Analog Integrator" by George H. Myers, presented at WESCON, Los Angeles, Calif., Aug. 21-24, 1956.*

The mechanical analog integrator common in navigational control systems, while accurate and wide in range, has moving parts which make it sensitive to vibration and environment. Because of this, the electronic analog integrator has made some inroads. But if the input to an electronic analog integrator is consistently of one polarity, the output of the integrator reaches such a large value that the integrating amplifier overloads.

It is possible to duplicate the wide range of the mechanical integrator by determining when an electronic integrator is "full" but not quite saturated, recording this fact with some type of counter, and then "emptying", or resetting, the integrator. The counter will indicate the number of times the integrator has been filled. A digital-to-analog converter will then transform the state of the counter, plus any charge existing in the integrator, back into a continuous voltage which other parts of the analog computer can use. The figure is a block diagram of a reversible electronic system that performs the functions described.




A conventional electronic integrator supplies its output to a "Positive Detector" and a "Negative Detector".

Each of these detectors produces a pulse when the integrator output voltage reaches either its maximum positive or negative allowable voltage (the postive detector operating for the positive voltage and the negative detector for the negative voltage). Either of these pulses causes the "Reset" to restore the integrator to its uncharged condition, but the pulse from the positive detector advances the "Electronic Counter" by one step while the pulse from the negative detector causes it to decrease by one step. The counter state is changed back into a voltage by the "Digital-to-Analog Converter". The voltage output of the converter may then be added to the integrator output (with a suitable scale factor), or the two outputs may be used separately as a coarse and fine indication, respectively, of the value of the integral. If a decimal counter is used, it may drive an indicator (such as a bank of lights or an Inditron tube) directly. A voltmeter across the integrator output would act as a vernier, or fine indicator.

A circuit built to demonstrate the set-reset action had these errors:

1. Reset error, the integration time lost while the integrating capacitor is discharged, 0.1 percent when the reset time is approximately eight times the reset time constant.
2. Detector error, 0.1 percent.
3. Digital-to-analog converter (when of the resistance-ladder type for ten binary digits), 0.4 percent if resistors are matched to within 0.05 to 0.1 percent, plus 0.1 percent variation in the battery supply voltage for the decoder.

Thus the errors of the devices used in the set-reset electronic integrator total, at the worst, 0.7 percent.

## Briefly Noted

*Circuit Equations for Rectifiers*—a systematic method for analyzing circuits containing piece-wise linear elements such as rectifiers and rectangular-loop magnetic cores. Method employs a specially-developed symbolism and algebra for formulating circuit equations that simplifies derivation of the final expressions. (Office of Technical Services, U. S. Dept. of Commerce, Order PB 111770, $1.)

The following catalogs are available from either OTS or the Library of Congress. They list, from a source of over 250,000 documents, pertinent references in the fields of:

- *Cermets* (CTR-319, 10 cents)
- *Transistors* (CTR-310, 10 cents)
- *Magnetic Amplifiers* (CTR-244, 10 cents)

## NEW BOOKS

### Computer Survey

A SURVEY OF AUTOMATIC DIGITAL COMPUTERS. *N. M. Blachman, J. B. Kruskal Jr., J. J. Wolf, and D. L. Hogan. 109 pp. Sponsored by U. S. Office of Naval Research. Sold by Office of Technical Services, Washington, D. C. $2.00.*

Under such table headings as Builder, Programming Service, Computing Time, Floor Area, Cooling, Best Suited, Power Consumption, Word Length, Operations Performed, Computing Element, Components, and so forth, the volume details some ninety-odd general-purpose machines. The introduction and several indices identify computers by name, and give their builders and their locations.

The survey is based on answers to questionnaires circulated in 1953, and thus does not cover the most recent computers. However, the information it does supply is of considerable interest.

### Russian Control Text

FUNDAMENTALS OF THE THEORY OF AUTOMATIC CONTROL (in Russian). *A. A. Voronoff. Edition 2, 470 pp. Published by State Publishing House for Technical Literature, Moscow, Russia. Approximately $3.50.*

The authors present a well-integrated account of basic servomechanism theory, centering attention on systems characterized by linear differential equations with constant coefficients. The prime tool of analysis here is the Laplace transform, the chief method of procedure is through use of transfer functions, and systems investigation is carried out in the frequency domain.

The principal topics treated are the basic ones of notation, definitions, structure of components and block diagrams; more advanced topics include determination of transient response, stability criteria, improvement of operating quality by various means of compensation, determination of transient response from frequency response and vice-versa, linearization of relay systems by describing function techniques, and phase-plane analysis.

Features of the book are the generous numerical examples and the many illustrations of how control applies to different branches of engineering. Its general thoroughness and its textbook design give the book

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## NEW BOOKS

great classroom value. The practicing engineer may find the illustrations of various electric, magnetic, mechanical, hydraulic, and pneumatic control devices and equipments of chief interest.

### Russian Servo Theory

FUNDAMENTAL THEORY OF LINEAR AUTOMATIC CONTROL (*in Russian*). *A. V. Fateev. 295 pp. Published by State Publishing House, Moscow. Approximately* $1.00.

The content of this basic textbook on servomechanisms, for students of electrical engineering, substantially parallels that of similar books published in this country, and thus it is likely that the engineer who reads it will find little that is new. It should, however, prove of interest to a teacher of control engineering, in that it contains some items not found in books in English. One is an account of Mikhailoff's criterion, which is particularly useful for determining the stability of a system when the characteristic equation, rather than the open-loop transfer function, is known. Several detailed illustrative examples, which can be used as student exercises or to idealize and then analyze the performance of actual industrial regulators, also find few counterparts in American textbooks.

*Thomas J. Higgins*
*Professor of Electrical Engineering*
*University of Wisconsin*

### Using Abacs

ABACS OR NOMOGRAMS. *A Giet. Translated from the French by J. W. Head and H. D. Phippen. 225 pp. Published by Philosophical Library, Inc., New York.* $12.00.

Earlier books on this subject have stressed mathematical concepts; here, now, is essentially a practical work written for engineers and physicists. No highly specialized mathematics is employed and the presentation consists almost entirely of examples from the fields of physics, mechanics, and electrical engineering. Problems are worked out in detail to demonstrate both the application and the construction of nomograms.

Types of charts discussed include Cartesian abacs involving any number of variables, alignment charts, and circular abacs. A standard approach to each problem enables the author

to develop an orderly method of attack, no matter how complex the relationship between variables. This procedure consists of: (1) reduction of the equation to a standard form; (2) arrangement of scales as to direction of graduation; (3) choice of moduli; (4) graduation and location of scales. In some cases, the relation between variables cannot be put into any of the standard forms. These cases call for auxiliary variables, to which an entire chapter is devoted. They enable the given relation to be split into several component parts, each of which may be put into one of the standard forms and then analyzed.

Of particular value is an appendix covering choice of methods and types of abacs. The author points out advantages and disadvantages, and simplifies selection of the appropriate type of chart determined by the equation's standard form.

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## Important Moves by Key People

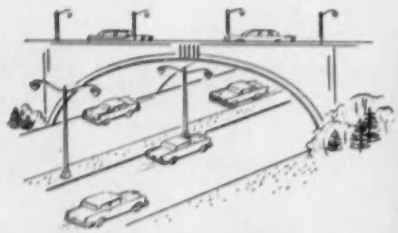
(from page 193)

sociated with Stanford University's Electronics Research Laboratory, Cal Tech's Jet Propulsion Laboratory, and Piper Engineering Co.

▶ **Joseph Swanson,** previously senior project engineer, has been advanced to the post of assistant chief engineer at Levinthal Electronic Products, Inc. Swanson is a specialist in high-power modulators and medical electronics. Before joining Levinthal, he was a staff member of the University of Pennsylvania's Moore School of Electrical Engineering and a research associate in the systems study and development group, Electronic Research Laboratory, Stanford University.

▶ **Oliver H. Fulton Jr.,** formerly assistant to the president, has been promoted to director of product planning for Underwood Corp. At the same time, **Edson I. Small** was appointed manager of market research. Fulton came to Underwood last year after a period as management consultant at Booz, Allen & Hamilton, and after extensive industrial experience in electronics development, engineering, and manufacturing. Small was formerly with Monroe Calculating Machine Co. in various sales management, market research, and administrative capacities.

▶ To handle its broadening scope of operations, Varian Associates has made several managerial shifts. **Russell Varian,** who has served as president, moves up to chairman of the board,




U.S. Patent No. 2658975

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Wherever snap action, ruggedness, dependability and long life are required, a "Snapper" relay is a safeguard of your circuit. It is being utilized in automatic controls for highway and street lighting, for control of time delay in business machines and the delay of application of plate voltage in thermionic tubes.

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ELECTRONICS DIVISION
CURTISS-WRIGHT
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## WHAT'S NEW

and **Sigurd Varian**, formerly vice-president for engineering, becomes president. Chairman Varian will devote much of his time to directing the expanding research activities of the company. **Emmet Cameron** fills the new position of vice-president in charge of the Tube Div., and **Ralph Kane** the post of V-P in charge of the Instrument Div. Cameron was previously V-P for production, Kane the Instrument Div.'s manager. Remaining as executive vice-president, general manager, and chief executive officer in charge of all company operations will be **H. Myrl Stearns.**

▶ Summers Gyroscope Co. has raised **Marvin B. Ruffin** to vice-president and general manager from vice-president, customer relations. Before joining Summers, Ruffin was chief engineer for Lear, Inc., and product manager for Magnavox Co.

▶ **Palmer E. Hakala**, an electronics engineer, has joined the staff of the Guided Missile Research Div. of The Ramo-Wooldridge Corp.

▶ **Gordon M. Piotrowski** has been appointed district application engineer for Clark Controller Co.

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| GD 62B | 0-3600 | | |
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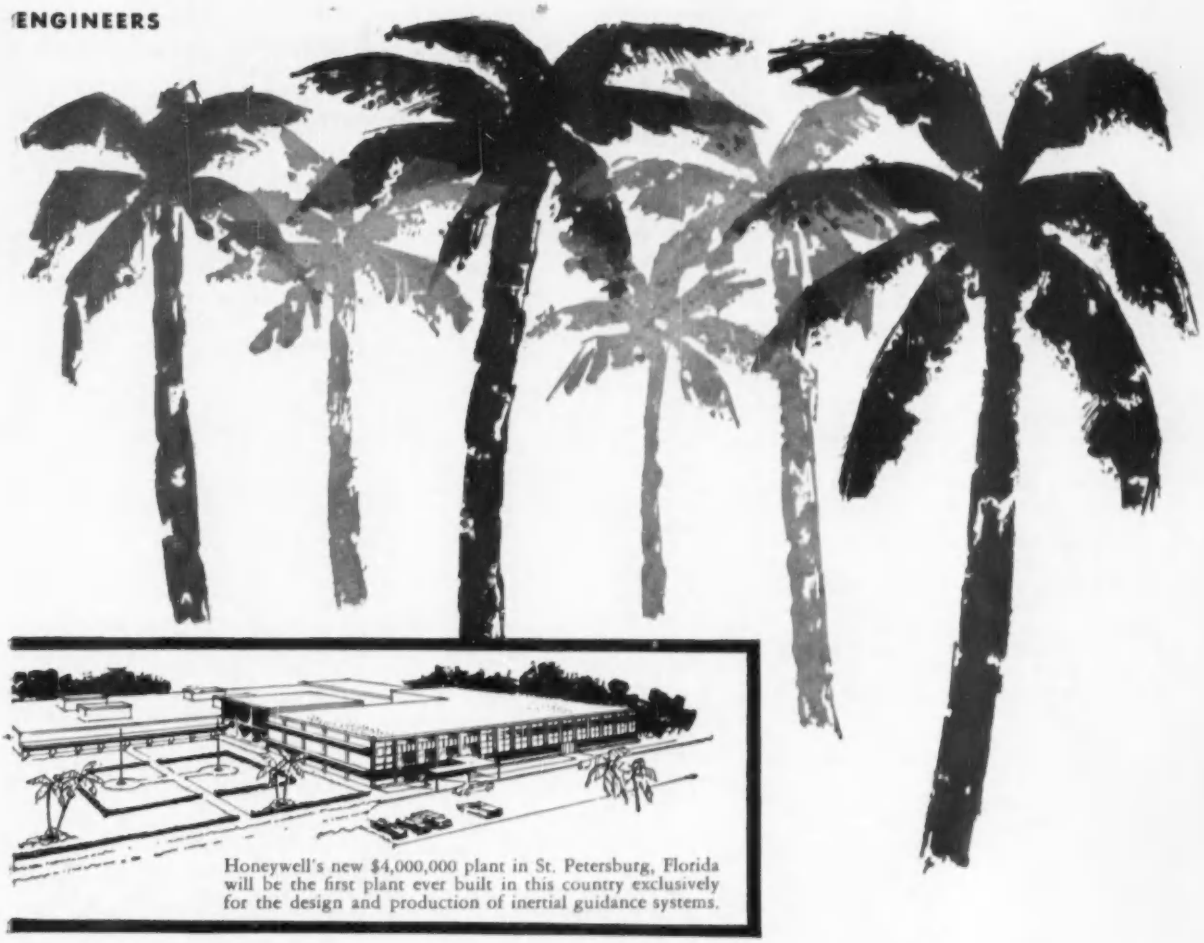
**ENGINEERS**



Honeywell's new $4,000,000 plant in St. Petersburg, Florida will be the first plant ever built in this country exclusively for the design and production of inertial guidance systems.

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## WHAT'S AHEAD: MEETINGS

### OCTOBER

**Institute of Radio Engineers,** Third Annual East Coast Conference on Aeronautical and Navigational Electronics, Fifth Regiment Armory, Baltimore, Md. Oct. 29-30

### NOVEMBER

**Instrument Society of America** (Philadelphia Section); Instrument Fair and Symposium on Automatic Data Processing Systems, Bellevue-Stratford Hotel, Philadelphia. Nov. 7-8

**NMAA, Second Annual Electronic Business Systems Conference,** P. O. Box 3584 Rincon Annex, San Francisco; Sheraton-Palace Hotel, San Francisco Nov. 15-16

**Third International Automation Exposition and Computer Clinic,** Trade Show Building, New York Nov. 26-30

**American Society of Mechanical Engineers,** Annual Meeting, National Exposition of Power and Mechanical Engineering, Hotels Statler and McAlpin, and Coliseum, New York. Nov. 26-30

### DECEMBER

**Institute of Radio Engineers,** Second Instrumentation Conference (nuclear instrumentation-industrial applications, missile and wind-tunnel instrumentation), Biltmore Hotel, Atlanta, Ga. Dec. 5-7

**Eastern Joint Computer Conference,** Institute of Radio Engineers, American Institute of Electrical Engineers, Association for Computing Machinery; theme: "New Developments in Computers", Hotel New Yorker, New York Dec 10-12

**Radio-Electronics-Television Manufacturers Association,** Symposium on Applied Reliability, Bovard Hall, University of Southern California, Los Angeles Dec. 19-20

### JANUARY

**American Institute of Electrical Engineers and Institute of Radio Engineers,** Symposium on Reliability and Quality Control, Hotel Statler, Washington, D. C. Jan. 14-15

**American Institute of Electrical Engineers,** Winter General Meeting, Hotel Statler, New York Jan. 21-25

### FEBRUARY

**Western Joint Computer Conference,** Hotel Statler, Los Angeles Feb. 26-28

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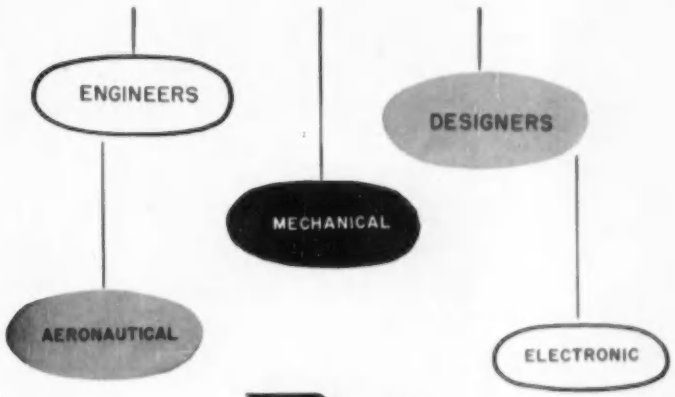


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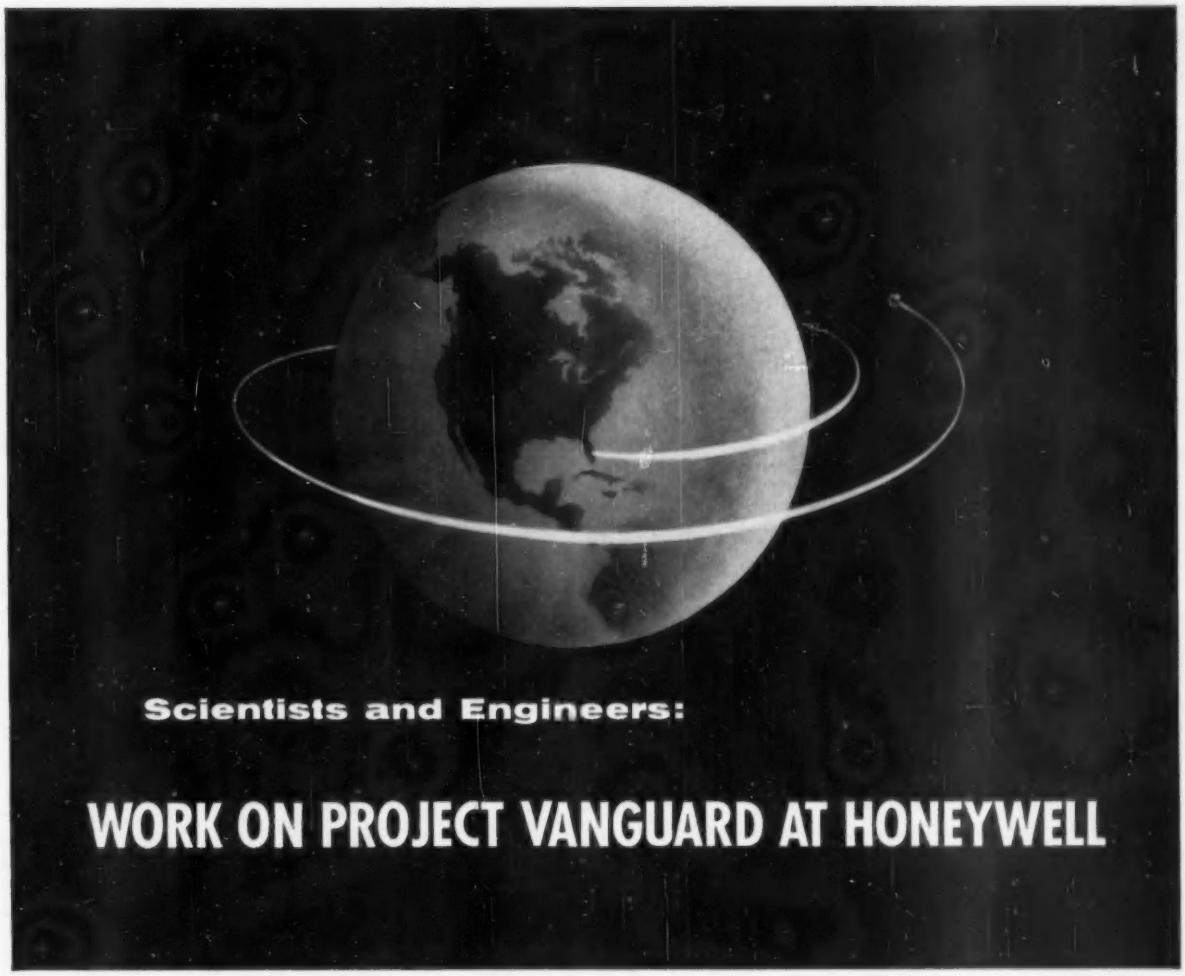


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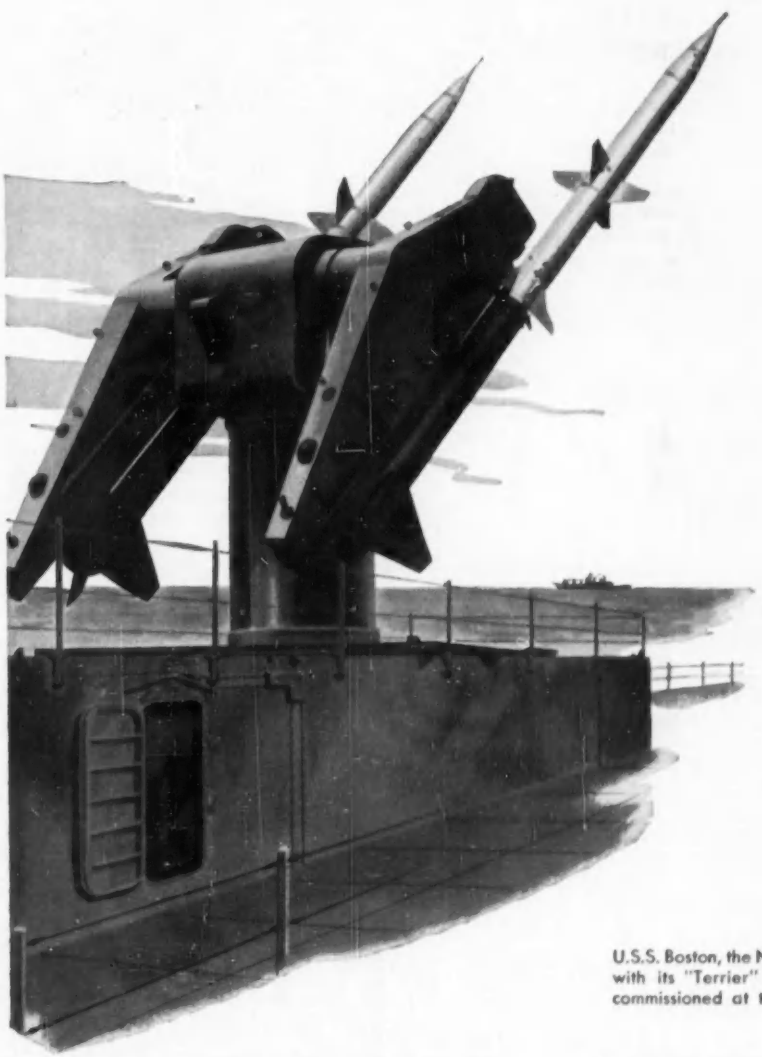

ONE OF THE MOST potent defense weapons now in use by our Navy is a supersonic, rocket-propelled, guided-missile called the "Terrier". Well named, the job of this electronically-controlled "watchdog" is to track down an enemy and put him out of action *before* he can strike.

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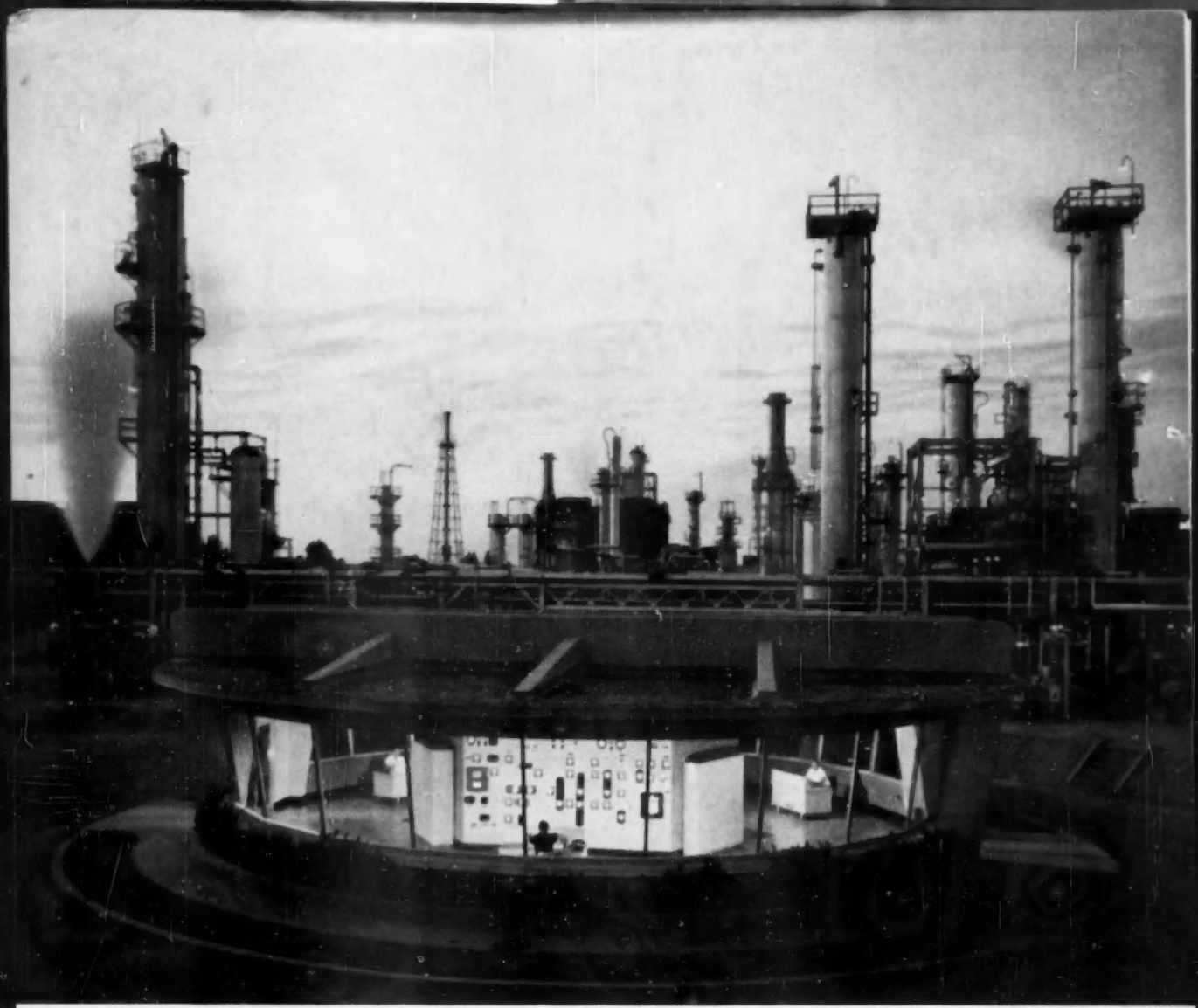

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